DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

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GEOLOGIC ATLAS

OF THE

UNITED STATES

COLFAX FOLIO

CALIFORNIA

INDEX MAP

SCALE: 40 MILES-1 INCH

AREA OF THE COLFAX FOLIO

AREA OF OTHER PUBLISHED FOLIOS

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FOLIO 66 | LIBRARY EDITION | COLFAX

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER

1900

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base map and geologic maps of a small area of country, together with explanatory and descriptive texts.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds: (1) inequalities of surface, called *relief*, as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called *drainage*, as streams, lakes, and swamps; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages, and cities.

Relief.—All elevations are measured from mean sea-level. The heights of many points are accurately determined, and those which are most important are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea-level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map:

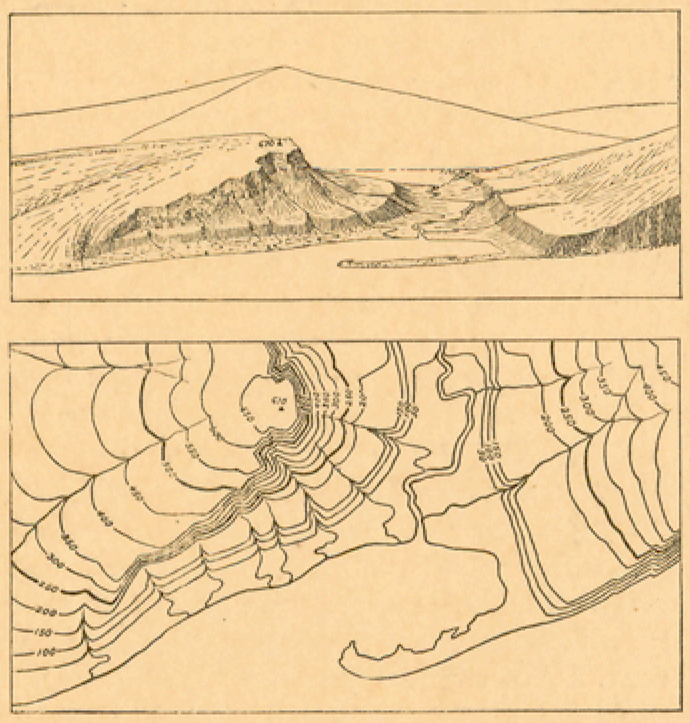


Fig. 1.—Ideal sketch and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand-bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply in a precipice. Contrasted with this precipice is the gentle descent of the left-hand slope. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

1. A contour indicates approximately a certain height above sea-level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea-level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The vertical space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. If the stream flows the year round the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the scale of the map. In this case it is "1 mile to an inch." The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to an inch" is expressed by $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents and corresponds nearly to 1 square mile; on the scale $\frac{1}{125,000}$, to about 4 square miles; and on the scale $\frac{1}{250,000}$, to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree, i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

Uses of the topographic sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known, and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it either consolidates in cracks or fissures crossing the bedding planes, thus forming dikes, or else spreads out between the strata in large bodies, called sills or laccoliths. Such rocks are called *intrusive*. Within their rock enclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock, it is younger than that rock, and when a sedimentary rock is deposited over it, the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in successive layers are said to be stratified.

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses, and as it rises or subsides the shore-lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quartzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus

DESCRIPTION OF THE COLFAX QUADRANGLE.

GENERAL FEATURES.

Geographic position.—The Colfax quadrangle includes the territory between 120° 30' and 121° west longitude and 39° and 39° 30' north latitude. The area is 34.5 miles long and nearly 27 miles wide, and contains 925 square miles. It embraces large portions of Sierra, Nevada, and Placer counties, as well as a little of Eldorado County, California.

Relief.—The quadrangle includes parts of the middle and upper slopes of the Sierra Nevada, but does not in any place reach the summit of that range. At the northeastern corner, however, the divide is only a few miles east. The relief is strongly marked. Numerous and deeply trenched V-shaped canyons divide the area into a great number of ridges with a trend varying from east to west to northeast to southwest. Many of these ridges are broad, of comparatively gentle relief, and slope, as does the rest of the range, in a southwesterly direction. Where the drainage lines are crowded the ridges become sharp and narrow. Following, for instance, the Southern Pacific Railroad, one may travel along one of these ridges and see comparatively little of the rugged features of the region, except when occasional turns of the road bring forth surprising glimpses of wild canyons with abrupt, rocky slopes, and bottoms 1500 to 2500 feet below the summits of the ridges. Were one to attempt to traverse the quadrangle from the northwestern to the southeastern corner in a straight line, it would be found a most laborious undertaking, involving the crossing of twenty or more canyons, most of them having precipitous walls. Up to an elevation of about 4500 feet the ridges are fairly regular in slope, but above this altitude the rise is much more rapid, the configuration is less regular, and the canyons, at least in the northeast quarter, are less sharply cut. Some peaks and short ridges project high above the general level of the eastern half of the quadrangle, and seen from below form conspicuous landmarks. Such are English Mountain, Black Mountains, Old Man Mountain, Signal Peak, Monumental Hill, and Duncan Peak. English Mountain, attaining an elevation of 8404 feet, is the highest point in the quadrangle; the canyon of North Fork of American River near the southwestern corner, having an elevation of only 900 feet, is the lowest.

Middle Fork and South Fork of Yuba River.

Drainage.—The quadrangle is drained by the various forks of Yuba and American rivers, which empty into the Sacramento River. All of these forks are torrential streams, flowing in sharply incised canyons, with no bottom lands excepting small gravel benches. The grades are very steep, and erosion is progressing rapidly where not interfered with by mining débris. The northern part of the quadrangle is drained by the Middle Fork of the Yuba and its tributaries, Oregon, Kanaka, and Wolf creeks, all of them entering from the north. Owing to the slope of the range and the direction of the main rivers, the latter mostly receive their tributaries from the north. In this quadrangle the average grade of the Middle Fork of the Yuba is 100 feet per mile. The South Fork of the Yuba, separated by the broad North Bloomfield ridge from the Middle Fork, has a general east-west direction and flows in a rather broad canyon. It receives as tributaries Humbug, Poorman, Canyon, Fall, and Fordyce creeks, all from the north. In this quadrangle the average grade is 100 feet per mile though only 60 or 70 feet in the western half of the area. Bear River occupies a small triangular watershed between the South Fork of the Yuba and the North Fork of the American. It flows in a narrow canyon, as a rule not above 1000 feet deep, and receives the Greenhorn and Steep Hollow rivers as tributaries from the north. The size of its canyon is manifestly out of proportion to the area of its watershed, and an examination of the relations near its head shows the reason for this. Half a mile north of Emigrant Gap, Bear River and South Fork of the Yuba approach within 2500 feet of each other, and a gap scarcely 100 feet above the former almost unites the two canyons. It is very clear that for some time the upper South Fork of the Yuba and Fordyce Creek formed the headwaters of the Bear and greatly increased the erosive power of that stream. At a comparatively recent date, by reason of the deepening of the canyon of the South Fork of the Yuba about 200 feet, the headwaters of that stream were turned from Bear River into their old channel. This probably happened when the upper sierra was covered by ice. The causes of this event are discussed below, together with the glacial phenomena. The grade of Bear River within this quadrangle averages 100 feet per mile.

North Fork and Middle Fork of American River.

The North Fork of the American River traverses the quadrangle in a narrow and rugged canyon, which in the eastern part of the area reaches a depth of over 3000 feet. Southeast of Colfax the river receives as tributaries Shirttail Canyon and Indian Creek, draining the Forest Hill divide, while farther up, southeast of Towle, the North Fork of the North Fork empties into it near Euchre Bar. The average grade of this river in this quadrangle from the southern boundary up to Euchre Bar is 55 feet per mile, while from Euchre Bar to the eastern boundary line it is 100 feet per mile. The Middle Fork of the American flows in a deeply incised canyon near the southern boundary line, receiving from the north the North Fork of the Middle Fork. The average grade of the Middle Fork in this quadrangle is 140 feet per mile.

Many small lakes of glacial origin are found in the northeastern corner of the quadrangle. The larger of these are Bowman, French, and Faucherie lakes. All of these and many more of the smaller lakes have been artificially dammed in order to serve as reservoirs, and their original size has thus been considerably increased.

Climate.—The climate, though varying greatly with the elevation, is in general temperate and is characterized by heavy precipitation during the winter and by dry, warm summers. Rain, however, falls occasionally during the summer in the northeastern part of the quadrangle. At Colfax, with an elevation of 2400 feet, the average rainfall, according to fourteen years' observation, is about 45 inches. Here snow may remain on the ground for a few weeks during the winter, and the lowest and highest temperatures recorded are 15° F. and 106° F. At Cisco, with an elevation of 6000 feet, the average precipitation is 57.41 inches. The snowfall here is very heavy, and the highest and lowest temperatures recorded are 9° F. and 96° F. At Bowman Lake an average of thirteen years gives the precipitation at 73 inches. In general, the precipitation may be said to increase northward and eastward.

Vegetation.—Nearly the whole of the Colfax quadrangle is included in the great forest zone of the Sierra Nevada. The only area outside of this zone is the northeastern part above the elevation of about 6000 feet. The ridges and to a considerable extent also the slopes of the canyons are covered by a luxuriant growth of timber, chiefly yellow pine (*Pinus ponderosa*) and sugar pine (*Pinus lambertiana*), together with much spruce and fir. Oaks also are found to some extent along the lower slopes, as, for instance, near Colfax and at other places along the western boundary. Even the steep slopes are densely covered with brush of various kinds, chiefly manzanita and ceanothus. Only the most rocky and inaccessible slopes are free from vegetation. Above an elevation of 6000 feet in the glaciated region of the sierra, the timber is sparse and of poor quality, consisting chiefly of tamarack, fir, and spruce. The ice sheet swept away the soil from large areas in this region, leaving the slopes and ridges completely bare. Thus the northeastern corner of the quadrangle east of a line from Cisco to Pinoli Peak offers a most striking contrast to the remainder, the extensive exposures of gray granite and dark-brown slates being particularly impressive.

A small grove of the so-called big trees (*Sequoia gigantea*) of California, consisting of half a dozen individuals, is found on a tributary to the Middle Fork of the American River, near the southeast corner of the quadrangle and about 5 miles east of Big Oak Flat. This is interesting and noteworthy, it being the most northerly occurrence of these trees in California.

Mining.

Industries.—The principal industries, in the order of their importance, are gold mining, timber cutting, cattle raising, and horticulture. The region embraces some of the most productive gold-mining districts in the Sierra Nevada, and both quartz and placer mining are actively carried on. Since the closing of the hydraulic mines, however, placer mining in Nevada County has suffered a considerable setback. Gold is mined practically over the whole area, the poorest region being that along the eastern boundary.

Lumber.

The lumber industry is important, the principal mills being located at Towle on the Southern Pacific Railroad. Along the line of the railroad nearly all of the valuable timber has been cut. Valuable bodies of timber still remain on the Forest Hill divide, on the ridges south of the South Fork of the Yuba, on the North Bloomfield divide, and on the ridges of the Sierra Nevada. By cattle raisers, the region is used chiefly as a summer range, the feed remaining green in the mountains when it is completely dried up in the lower valleys, where the ranches are located.

Horticulture.

Horticulture is carried on on a small scale at all settlements below 5000 feet. Near Colfax the industry is of considerable importance, large areas being covered by vineyards and pear orchards. A little higher up on the slope, as, for instance, near Dutch Flat, the apple grows to perfection and large orchards of this fruit have been planted.

Railroads.

Means of transportation.—The Southern Pacific Railroad traverses the quadrangle diagonally, and is located on the ridge between Bear River and the North Fork of the American. The railroad is protected by snowsheds extending from Blue Canyon to far beyond the eastern boundary of the quadrangle.

Wagon roads.

Two of the principal wagon roads across the mountains traverse the quadrangle, one, the so-called Henness Pass road, following the North Bloomfield ridge, the other, the Donner Pass road, following the line of the railroad.

Settlements.—Nevada City, the county seat of Nevada County, is situated on Deer Creek, less than one mile west of the western boundary of the quadrangle. There are a number of small mining towns with a few hundred inhabitants scattered over the region. These are North Bloomfield, Moores Flat, Graniteville, North Columbia, and Washington in Nevada County; and Colfax, Dutch Flat, Gold Run, Iowa Hill, Forest Hill and Michigan Bluff in Placer County.

Water supply.—The abundant water supply has been extensively utilized to provide water for the hydraulic mines, and lately also to supply the needs of irrigation in the horticultural districts in the valleys.

Irrigation ditches.

The principal ditches are as follows: The Milton ditch takes water from the Middle Fork of the Yuba at Milton, about 10 miles from English Mountain, and carries it down to the hydraulic mines near San Juan. Its capacity is 3000 miner's inches. The San Juan ditch takes water from the same river a short distance above Bloody Run. The Eureka Lake Company's ditch utilizes Faucherie and French lakes as reservoirs and carries the water down to North Columbia. It has a capacity of 5800 inches. North Bloomfield ditch has a capacity of 3200 inches, and utilizes Bowman Lake as a reservoir, taking the water down to the gravel mines of North Bloomfield. The ridge between the South Fork of the Yuba and the North Fork of the American is supplied with water by the South Yuba Company, which utilizes the headwaters of the South Fork of Yuba and the lakes in that region mapped on the Truckee sheet as reservoirs. The ditches of this company, including that taking the water from Bear River near Colfax, follow the various ridges down to the mining districts of Nevada City, Grass Valley, Quaker Hill, You Bet, and Dutch Flat, and continue still farther west to the horticultural districts of Auburn and Newcastle. The total capacity of the South Yuba Company's ditches is 10,000 inches. The Blue Tent ditch, supplying the gravel mines of the same name, takes its water from the South Fork of the Yuba above Emigrant Gap, and has a capacity of 2100 inches.

Besides these there are a number of smaller ditches both in Placer and Nevada counties. The waters of the North Fork and the Middle Fork of the American River are not utilized at present. It has, however, been proposed to build a ditch from near Euchre Bar on the North Fork, which would supply the land in the vicinity of Auburn and Newcastle with water for irrigation.

GEOLOGY.

BED-ROCK SERIES.

Under this general heading are included all of the older rocks of the Sierra Nevada, consisting of sedimentary rocks deposited during or before the Juratrias period and effusive or intrusive igneous rocks, which mostly date from the Juratrias period, or possibly in part from the early Cretaceous. None of the igneous rocks belonging to the Bed-rock series in this quadrangle are younger than the early Cretaceous and probably none are older than the Juratrias.

SEDIMENTARY ROCKS.

Three groups of sedimentary rocks.

As usual in the Sierra Nevada, the fossil evidence of age is very scant, but it is confidently believed that the sedimentary rocks of the Bed-rock series may be divided into three groups: 1. The Carboniferous group, equivalent to the Calaveras formation of other folios. In this quadrangle this group can be subdivided into five formations, lithologically very distinct, though the fossils do not afford data for paleontologic discrimination. These are enumerated from east to west as follows: Blue Canyon formation, Relief quartzite, Cape Horn slates, Delhi formation, and Clipper Gap formation. 2. The older Juratrias, or Sailor Canyon formation. 3. The younger Juratrias, or Mariposa formation.

The sedimentary rocks consist of clay slate, quartzitic sandstone, limestone, and chert, all metamorphosed near the granite contact to schist and quartzite. All are greatly disturbed, and most of them have been strongly compressed. The igneous rocks consist partly of diabase, diabase tuff, gabbro, peridotite, serpentine, porphyrites, the schistose forms of these rocks resulting from pressure, and partly (and predominantly) of granitic and dioritic rocks, all of which are probably somewhat later than the Juratrias sediments.

CARBONIFEROUS PERIOD.

Blue Canyon formation.—To the east of the great serpentine belt which traverses the entire quadrangle from north to south is the main Carboniferous area. These rocks have been called the Blue Canyon formation, the name being derived from the village on the line of the railroad. The formation occupies nearly the whole southeastern corner of the quadrangle, being adjoined on the east by the Juratrias rocks of the Sailor Canyon formation. In the northern half its area is reduced by large masses of intrusive granite. The general petrographic character of the series is very constant and similar throughout, except in a small belt near its eastern boundary. It consists of clay slates and quartzitic sandstones. The clay slates are black and very fissile. The quartzitic sandstones are dark gray and, as a rule, fine grained. They are of very quartzose character and have been subjected to considerable compression, which has imparted to them a rough schistosity. Conglomerates are as a rule absent, the only occurrence noted being a rather fine quartz conglomerate in the canyon of the South Fork of the Yuba 3 miles above Washington. A few limestone lenses occur as marked on the map in the canyon of the North Fork of the American.

Clay slates and quartzitic sandstones.

The narrow area of sedimentary rocks extending from Emigrant Gap toward Pinoli Peak and surrounded by granitic rocks differs in character to some extent from the main series. The rocks consist of clay slate together with large masses of grayish quartzite and a black, hard sedimentary rock showing but little stratification. There is also a well-marked belt of limestone extending from Fall Creek Mountain to near Pinoli Peak, which would probably be found to be continuous if the exposures were perfect. Near the contact with the Sailor Canyon formation the petrographic character differs again to some extent from that shown in the rest of the area. From Duncan Peak there extends across the North Fork of American River to the vicinity of Monumental Hill a belt of gray or brown chert, referred to as the Duncan chert. It is well exposed in the canyons near Canada Hill and in the canyon of the main river. This chert is in all probability not of clastic origin, and may have been derived from limestone by a process of silicification. On the surface of the ridges the Blue Canyon formation decomposes to a light-colored, poor, siliceous soil containing fragments of quartzite. Good outcrops are found only along the canyons where the character of the formation may be studied to great advantage. The strike and dip of the schistosity coincides as a rule with that of the strata. Dips measured on the steep canyon sides and on the summit of the ridges are rarely reliable because of the weathering of the rocks. Near the southern boundary the series has a northeasterly direction and a vertical or steep easterly dip. In the main part of the area the strike is north-northwest and the dip is steep to the east. A marked exception to this rule is noted in the area extending between the serpentine belt and the granite mass of South Poorman. Here the schistosity has a northerly direction and the dip over large areas is from 50° to 90° W. Near the northern boundary of the quadrangle the normal easterly dip appears again. Along the North Fork of the American River from east of Mumford Bar to Granite Canyon the schistosity, which is nearly vertical, has a marked northwest-southeast or even east-west direction. This is local, however, as north and south of this vicinity the normal direction again asserts itself.

Schistosity.

Owing to the petrographic character of the series, the strike and dip of the strata may often be accurately observed, and in the majority of cases it coincides closely with the schistosity, as, for instance, in the canyon of the South Fork of the Yuba above Washington and in the canyon of the North Fork of American River near Euchre Bar. Occasionally, however, the dip of the schistosity and strata may differ, as in a case noted 1½ miles above Mumford Bar. Here the schistosity is vertical, while the strata dip 60° E., as is made apparent by a small bed of limestone embedded in the slates.

Strike and dip of Blue Canyon formation.

The narrow belt between the granite areas shows strata and schistosity with a northeasterly direction and a steep westerly dip. The quartzites and slates in the vicinity of Bowman Lake swing gradually around from a northeasterly to a northwesterly strike. The dip of the strata appears to be constantly to the east and at smaller angles than are usually met with. It ranges from 35° to 80°.

Only two fossil localities have been found in the Blue Canyon formation. One is situated in the canyon of the North Fork of American River on the trail from Cisco to Sailor Canyon, at a point between the river and Granite Canyon. At the contact with the Sailor Canyon formation lies a small lens of crystalline limestone having a width of perhaps 100 feet, which farther north and south appears to change into cherty masses. In this limestone poorly preserved fossils were found, none of which can be satisfactorily determined. The forms found were as follows: *Lithostrotion*, crinoid stems, *Aviculopecten*, lamellibranch (elongate shell) and *Murchisonia*. These forms indicate nothing more definite than a Paleozoic age. The second fossil locality is found in the large limestone mass southwest of Pinoli Peak in Poorman Valley. This limestone appears to contain corals resembling *Syringopora*, *Diphyphyllum*, or *Lithostrotion*, as well as crinoid stems. Here again the evidences point to nothing more definite than a Paleozoic age.

Fossils of Blue Canyon formation.

Along the contact of the main granitic area the Blue Canyon formation and the Juratrias present strong evidence of contact metamorphic action. The altered zone is as much as a mile wide, the metamorphic action being most intense at the contact. Here clay slates are converted to gneissoid schist and mica-schists, while calcareous rocks are changed to a dense gray or brown hornfels. Limestone masses, as, for instance, those near Fall Creek Mountain and on the hill southwest of Faucherie Lake, are made highly crystalline and filled with garnets, epidote, wollastonite and other characteristic contact minerals. Near the diorite and gabbro contact metamorphoric action appears less intense. The contact itself is nearly always sharp, and as distinct, usually, as if drawn with a pencil. An excellent place to study the relations of the rocks is along the beautifully exposed contact from Emigrant Gap up to Grouse Ridge.

Contact metamorphism.

Relief quartzite.—From Relief to Dutch Flat the Relief quartzite forms a narrow belt adjoining the Cape Horn slates. North and south of these points this formation is cut out by the broadening serpentine belt. The best exposures of this formation are found in the canyons of the South Fork of the Yuba below Relief, of Bear River, and of Steep Hollow north of Dutch Flat.

The Relief quartzite consists of a very hard grayish or yellowish siliceous rock of fine grain and clastic origin. It might be characterized as a very fine-grained quartzite alternating with streaks of siliceous clay slates. This belt shows stratification very plainly. The general direction is from north to south and the dip is nearly vertical. In detail, however, the stratification planes are exceedingly crumpled and twisted, as if by the action of a compressing force acting horizontally in the perpendicular plane of stratification. Moreover, the quartzite is completely filled by small irregular bunches and veinlets of white quartz. No fossils have been found in this formation.

Fine-grained siliceous rock.

Cape Horn slates.—A short distance east of Colfax the Mariposa formation is adjoined by the Cape Horn slates, which extend as a belt from the southern to the northern boundary of the quadrangle. The name is derived from the prominent point called Cape Horn, overlooking the canyon of the North Fork of American River. This belt has a width of 2 miles at the southern boundary and of 5 miles near Colfax, and narrows northward gradually until in Sierra County its width is only 1½ miles. The characteristic rocks are fissile typical clay slates, almost black when fresh and weathering to a gray or silvery-white color. Small limestone lenses are found below Cape Horn, in Bear River Canyon west of Dutch Flat, and in the canyon of the South Fork of the Yuba south of Relief. They are ordinarily only a few feet thick.

Fissile clay slate.

On the surface of the ridges the formation weathers to a poor, light-colored soil mixed with many small slate fragments. Along the canyons excellent exposures are found; among the best are perhaps those in the North Fork of the American River, easily accessible by the trail from Colfax to Iowa Hill. The strike of the schistosity is from north to north-northwest, the dip almost constantly from 80° to 90° ENE. Occasionally, however, as in Bear River southwest of Dutch Flat and in the Middle Fork of the Yuba northwest of Moores Flat, steep dips to the west are noted. The strike and dip of the strata can only rarely be determined with certainty. In Bear River Canyon southwest of Dutch Flat these limestone lenses inclosed in slate dip 45° W.

The only fossils thus far found in the Cape Horn slates occur in the little limestone mass below Cape Horn on the trail from Colfax to Iowa Hill. They consist of round crinoid stems, probably indicating a Paleozoic age.

Fossils of Cape Horn slates.

Delhi formation.—The division of the Carboniferous appearing west of the Cape Horn slates is the Clipper Gap formation. A short distance north of Colfax there begins, however, a new formation, very characteristic as to its petrographic character, to which the name Delhi has been given, from the Delhi mine, near which it is typically developed. It occupies an area along the northern half of the western boundary line, continuing over into the Smartsville quadrangle westward and the Downieville quadrangle northward. A narrow belt of eruptive rocks separates it from the Cape Horn slates on the east. In the vicinity of the lower Greenhorn River the formation borders with fairly distinct contacts against the same slates. In its general petrographic character the formation consists chiefly of a peculiar dark-brown or black hard rock, so fine grained as to be almost flinty and rarely showing either stratification or schistosity. In many places the similarity to the particular product of contact metamorphism called hornfels is very striking, and the dark-brown color is due to newly formed biotite. The rock has often a chert-like appearance, but it contains less silica than the normal chert. Wherever a somewhat coarser structure permits a microscopic diagnosis this rock is found to be of clastic character. The peculiar petrographic character is probably due to regional metamorphism acting on fine sediments of a certain kind. Very few lenticular limestone masses occur in it, the largest being found at the mouth of Missouri Canyon, 3 miles south of North Bloomfield. In a few places, as, for instance, near Edwards Bridge, the series shows a marked schistosity, and the direction of the dip is, as usual, east-northeast at steep angles. This schistose rock has the appearance of a dark, siliceous clay slate.

Dark-brown, or black fine-grained rock.

On the surface of the ridges the Delhi formation is decomposed to an often deep, light-colored soil, sometimes, as, for instance, one mile east of Plum Valley, almost white in color. In the canyons of Oregon Creek and the two forks of the Yuba, the formation is beautifully exposed, showing miles of hard, massive, dark-brown sedimentary rock. Near the Federal Loan mine, east of Nevada City, the Delhi formation adjoins an intrusive area of granodiorite and is for a distance of about a quarter of a mile greatly metamorphosed, the result being a more or less coarse, typical hornfels. No notable metamorphism appears along the diorite area near Edwards Bridge.

The only fossil locality found in this formation is in the limestone mass referred to above. This contains numerous pieces of large, round crinoid stems, indicating in all probability a Paleozoic age.

Clipper Gap formation.—This formation comprises the Carboniferous sedimentary rocks lying to the west of the Mariposa slates, the name being taken from a village in the adjoining Sacramento quadrangle. The formation is extensively exposed in the Sacramento and Placerville quadrangles, where, however, it has been included in the Calaveras formation. In this quadrangle it is represented only by a small area in the southwestern corner. To the north and northwest it is cut off by large areas of basic eruptive rocks. In the Smartsville quadrangle only a few fragments of this formation appear embedded in the diabases and porphyrites.

The rocks consist of a highly compressed sequence of black clay slates and dark argillaceous sandstones. Bodies of limestone are abundant but they are usually lenticular and are not continuous for great distances. Bluish or grayish chert is also common, and is so closely connected with the limestone as to strongly suggest its derivation from that rock by a process of silicification.

Black clay slates and argillaceous sandstones.

The cherts appear to be most abundant along the eastern contact from Weimar to Howell Hill, while clay slates are more prominent in the western part. The chert does not ordinarily show stratification. In one place, however, on the road leading down from Howell Hill to Bear River, it is markedly banded, showing the dip and strike very plainly. The clay slates are dark gray when fresh and break in irregular fragments without pronounced fissility. The relief of the area, rounded hills and ridges, is not very marked. The surface is deeply disintegrated and outcrops are very rarely found except in the canyons and on steep slopes. The hills are covered by a deep reddish soil which contains small fragments of chert that have escaped decomposition. The few outcrops met with usually consist of gray or bluish chert. The strike and dip can be observed only in the canyons and ravines. The dip is rather uniform, generally averaging 80° ENE. The schistosity and stratification coincide.

The identification of this series as probably Carboniferous rests on the fossils found at three localities. The first locality is in the Placerville quadrangle, in a small limestone mass on the south side of the canyon of the Middle Fork of the American River 2 miles above Mammoth Bar. In this place crinoid stems and sections of shells were found, the latter, however, in poor preservation. The second locality is in the Placerville quadrangle three-fourths of a mile southeast of the southwestern corner of the Colfax quadrangle. It is apparently from exactly the same horizon as the first. The formation here contains a small lenticular mass of limestone in which a coral (*Phillipastrea*) and a gasteropod (*Pleurotomaria*) were found. The remains could not be specifically identified. The third and most interesting locality is located on the east bank of Bear River Canyon 2 miles due west of Colfax. A large outcrop of crystalline limestone here appears, a few hundred feet wide and long. This mass is adjoined by the typical Mariposa slates on the northeast and south, while across the river is a large area of porphyritic diabase. The mass is thus disconnected from the main area of the Clipper Gap formation, and it is probable that it is a fragment torn loose from it at the time of the diabase eruption. In this crystalline limestone were found the following fossils: crinoid stems, *Clisiophyllum gabbi* Meek, *Lithostrotion whitneyi*, and brachiopod fragments of various species. These are the best Carboniferous fossils thus far obtained from this region and they can be unhesitatingly referred to the lower Carboniferous. A small area continuing into the adjoining Smartsville quadrangle and consisting of siliceous rocks and clay slates, appears about 3 miles northwest of Colfax. It is embedded in volcanic rocks, and probably belongs to the Clipper Gap formation.

Fossils of Clipper Gap formation.

JURATRIAS PERIOD.

Sailor Canyon formation.—This series, named from a small tributary of American River, adjoins the Blue Canyon formation eastward near the eastern boundary of the quadrangle and extends over into the Truckee quadrangle. The belt, which is from 2 to 3 miles wide, extends from north-northwest to south-southeast for about 10 miles, terminating at Signal Peak. An intrusive mass of granitic rocks there intervenes, but 7 miles northward, on both sides of English Mountain, sedimentary rocks are again noticed, which probably belong to the same formation, though no fossils have thus far been found in them. In the southern area the contact line between Carboniferous and Juratrias can be established without much doubt, but in the northern area the line of demarcation is much more uncertain. It lies between the Carboniferous limestone zone and the quartz-porphyry dike just east of Bowman Lake. This limestone zone forms a definite horizon from Pinoli Peak to Emigrant Gap, and its continuation is probably represented by the cherts of Duncan Peak and Big Valley.

The southern area consists of black calcareous shale, without pronounced fissility, interbedded with subordinate strata of quartzite and limestone. The dip is fairly constant, ranging from 50° to 70° ENE. The stratification is plainly visible, being especially well shown in the reddish-brown bluffs forming the northern slope of the canyon of American River. The schistosity is far less strongly marked in this series than in the older sediments to the west of Sailor Canyon. If the beds really form one unrepeated series, the total thickness must be no less than 6000 feet and possibly 10,000. But the formation has not been studied in sufficient detail to permit the assertion that such a thickness exists. In the canyon of American River the formation rests on a heavy bed of chert grading into limestone, the course of which is plainly visible along the canyon slope. This chert bed has a general northwest strike and a steep dip, changing from east to west. The basal part of the Sailor Canyon formation, resting on this chert, is a closely packed conglomerate of chert and slate. West of the chert bed the schistosity becomes strongly marked and has a strike ranging from northwest to southeast to west to east. All the relations observed point

Black, calcareous shale.

strongly to an unconformity between the Juratrias and the Carboniferous.

Fossils of Sailor Canyon formation.

One of the principal fossil localities is on the western side of Sailor Canyon along the trail to Canada Hill, a few hundred feet above Sterrett mine. Many poorly preserved ammonites and shells of *Daonella* were found here in the black calcareous shale. Again imperfect ammonites and casts of shells were found at several places along the bed of Sailor Canyon. At the mouth of New York Canyon the beds contain *Monotis* shells. The fossils, though imperfect, indicate a Juratrias age, the time of deposition probably ranging between the upper Trias and the lower Jura; thus the beds are older than those in the Mariposa formation.

Contact metamorphism.

Toward the northwest the formation is cut off by granodiorite and is strongly metamorphosed near the contact. In fact, the whole wedge of sedimentary rocks near Cisco appears influenced by contact metamorphism. The calcareous slates are altered to hard black hornfels showing no stratification; the quartzites appear more crystalline. These metamorphic beds form the flat top of Signal Peak, while granitic rocks crop below on the northeast and west. The reddish brown of the sediments contrasts very strongly with the white of the granodiorite, and the whole produces distinctly the impression that the former rest like a torn fragment upon the latter. The summit and western part of Signal Peak contain many dikes of granite-porphyry and diorite-porphyry, one prominent dike projecting from the main granodiorite area far into the sedimentary mass.

Two divisions in northern area of Sailor Canyon beds.

The northern area, forming the supposed continuation of the Sailor Canyon beds, is divided into two parts. The western part, between the quartz-porphyry dike and English Mountain, consists of black, hard slates with but little fissility, alternating with gray or white quartzite or quartzitic sandstone and narrow bands of a yellowish-gray limestone. The strike and dip of the strata are very well defined, the latter being from 35° to 60° E. and apparently dipping below the eruptive masses of English Mountain, just as in the Truckee quadrangle the beds dip below the diabase-porphyrite of Snow Mountain. Small streaks of a black, fine-grained tuff are intercalated in the diabase-porphyrite of English Mountain with a dip of from 25° to 35° E. The outcrops in Jackson Creek are much obscured by morainal débris.

The eastern part of the area northeast of English Mountain consists of indistinctly stratified quartzite alternating with yellowish-gray limestone. All along the granite contact from Culbertson Lake to English Mountain this series is marked by contact metamorphism, the limestones being converted to masses of garnets and other contact minerals and the slates to mica-schists. Some of the rocks northeast of English Mountain also show strong indications of contact metamorphism.

Black shale or slates, dark-gray sandstones, and conglomerate.

Mariposa formation.—This formation, the most recent part of the Bed-rock series, occupies a small area in the southwestern part of the quadrangle; this is the northern end of the long belt of Mariposa slates, traceable from Mariposa County. Its northward continuation is cut off by masses of diabase-porphyrite and by the Delhi formation, which outcrops from this point northward. The Mariposa slates form a belt from 2 to 3 miles wide, bordered on the west and east by older Carboniferous strata. The formation contains a number of small greenstone dikes, and along its eastern and western contacts lie many dikes of serpentine and amphibolite. Its northern end is divided by a projecting mass of gabbro and diabase. The formation is distinctly different petrographically from the surrounding Carboniferous rocks. It consists of black shales or slates, usually not very fissile, alternating with dark-gray sandstones of coarser or finer grain, and a great number of conglomerate beds. The rocks are tuffaceous, contain much iron, and weather into a deep reddish-yellow soil. Good outcrops are found only in railroad cuts or along ravines and canyons. The conglomerate beds, which are very numerous, though rarely very thick, are most abundant and best exposed along Bunch Canyon, near Colfax, and in the canyon of the American River at the southern boundary of the quadrangle. In the western part of the area they are less common. The pebbles consist predominatingly of chert, quartz, slate, and limestone evidently derived from the older Clipper Gap formation, but volcanic material, diabases, and porphyrites are also present, giving the sediments a strongly tuffaceous aspect. The formation was clearly deposited in a gulf or shallow bay, the conglomerates indicating the immediate proximity of the shore line.

Strike and dip of Mariposa formation.

The strike and dip of the strata are usually easily deciphered. The strike is ordinarily north-westerly, though sharp changes may be noted. The dip is decidedly less than that of the surrounding Carboniferous slates, being 25° to 80° E. Occasionally the strike swings around to east-west, as in Liveoak Ravine near Bunch Canyon. The dip is here 45° S. The schistosity has generally a north-northwest direction and steep easterly dip, by no means always coinciding with the stratification. The first mentioned locality illustrates this strikingly.

The best exposures of the contact of the Mariposa formation with the Cape Horn slates are found along the western side of Cape Horn. The black Mariposa slates, dipping at a moderate angle east, are closely adjoined by the fissile, silvery-white Cape Horn slates, standing nearly vertical. No fault is visible, but there is almost certainly an unconformity.

Fossils in Mariposa formation.

Characteristic fossils have been discovered at only two places. The first locality is at a railroad cut one mile south-southwest of Colfax, one ammonite, *Perisphinctes colfaxi* Gabb, having been found here. The other locality is at Irving's ranch, $1\frac{1}{4}$ miles south-west of Colfax, where specimens of the ammonite *Olcostephanus lindgreni* Hyatt, occur in a rusty-brown, sandy slate. The fossils point to the uppermost Juratrias.

IGNEOUS ROCKS.

Greenstone series.—Under this head are comprised a number of rock species, occurring chiefly in the western part of the quadrangle. They consist of diabase, diorite, gabbro, peridotite, pyroxenite, porphyrites, amphibolite, and serpentine. They are poor in silica, rich in iron and magnesia, are generally dark green, and in structure range from granular to porphyritic. They appear to be very intimately connected genetically, so that contacts are often difficult to draw. Compressive stresses have acted more or less intensely on all of them, often producing a slaty or schistose structure over ill-defined areas. It is not possible to separate sharply the schistose or dynamometamorphosed portions from those not so affected. For these reasons it has seemed better to describe these areas by geographic rather than by petrographic divisions.

In this description are not included the diorites, gabbros, and peridotite in the eastern part of the quadrangle, which genetically belong to the granodiorite series and are best described in connection with that group of rocks.

Pike area.

This series, which continues over into the adjoining Smartsville, Downieville, and Bidwell Bar quadrangles, consists of a variety of rocks. In the northwestern corner of the quadrangle is an area of massive amphibolitic rocks, evidently largely derived from a diorite or diorite-porphyrite. Adjoining this is a large area of serpentine, which contains unaltered peridotite on the northern side of the lava ridge on the slopes of Indian Creek. Near Pike there is an area of diabase-porphyrite having extremely irregular outline. The rock is dense, dark-green, of altered aspect, and contains in places much chlorite and serpentine. At the Alaska mine the rock in hanging and foot walls is a chloritic schist; ordinarily, however, the rock is not very schistose. Most of the fresh rock appears to be a fine-grained breccia of diabase-porphyrite, the augite of which often is converted into uralite.

The relations of this series to the sedimentary series are not established beyond doubt. Dike-like masses project into the slates, and in turn contain as inclusions masses and slabs of sedimentary rocks. Most of the complicated areas occur on the ridges, where exposures are poor. In the canyon of the Middle Fork of Yuba River also the contact is unsatisfactorily exposed. The rocks should probably be regarded as intrusive into the sediments, and not as interbedded masses. A system of long dikes of the same rock crop north and south of North Columbia. A specimen from near Kennebec House proved to be a brecciated diabase-porphyrite, much altered by pressure.

Diorite of North Columbia and Edwards Bridge.

Small areas of an intrusive medium-grained diorite occur a short distance east of North Columbia and at the head of Grizzly Creek. These may possibly be connected below the cover of lava and gravel. Between Edwards Bridge and Blue Tent a similar area adjoins the granodiorite of Nevada City, from which it is separated by an often indistinct contact; it may, indeed, be part of the same intrusión, somewhat richer in iron and magnesia. At Edwards Bridge the rock is a diorite-porphyrite, but at other places and in the adjoining Smartsville quadrangle it appears as a diorite or gabbro.

Delhi gabbro dike.

In the Smartsville quadrangle the granodiorite is, north of Badger Hill, adjoined by an area of gabbro which may be regarded as a facies or basic development of that intrusive mass. From this area a dike projects into this quadrangle on Grizzly Ridge, southwest of the Delhi mine. It is as a rule a coarse-grained, dark rock consisting of lime feldspar, diallage, hypersthene, and olivine, though near the contacts finer-grained varieties occur which probably are diorites in part.

Colfax gabbro and diorite.

To the northwest of Colfax extends an elliptical mass of coarse, basic rock consisting of dark-green diallage or hornblende and greenish lime feldspar. The contacts with the surrounding porphyrites are often extremely indistinct.

Banner Hill porphyrite.

The southern slope of Banner Hill is occupied by hornblende-porphyrite and augite-porphyrite, which are often mixed in a coarse breccia. A little farther south in the same area the rock changes to a diabase of varying grain, which character it retains on the ridge between Greenhorn River and Clipper Creek.

Bear River porphyrite.

Bear River, in the southwestern corner of the quadrangle, forms approximately the dividing line between the great porphyrite and diabase area of the foothills, developed so extensively in the adjoining Smartsville quadrangle, and the sedimentary rocks. This area consists largely of old effusive rocks, in other words lavas, of Mesozoic age. The rock is dark green, fine grained, and often very chloritic. A rough schistosity was noted along the upper road from Colfax to Grass Valley southwest of Buena Vista. A typical specimen taken about 2 miles south-southwest of Buena Vista proved upon microscopic examination to be a fine breccia or tuff of diabase-porphyrite. Dikes and dike-like masses of gabbro are injected into the porphyrite.

A small serpentine belt follows the western contact with the Mariposa slates; along the eastern contact with the same slates lies a narrow zone of finer-grained and porphyritic diorite. A dike-like mass of gabbro also adjoined by serpentine is exposed along Greenhorn River near the Nevada County Narrow Gauge Railroad.

Serpentine in Mariposa formation.

A number of small serpentine areas, mostly of dike-like or lenticular form, are inclosed in the Mariposa slates. One long dike extends from Howell Hill to Weimar, along the contact of the Clipper Gap formation; another lenticular mass adjoins the amphibolite on the Colfax-Iowa Hill road. All these serpentine areas have probably been derived from pyroxenites and peridotites.

Amphibolite of North Fork, Secret Canyon, and Gold Run.

A long area of schistose, dark-green, fine-grained amphibolite extends from south of Spanish Dry Diggings, in the Placerville quadrangle, to beyond Colfax. Through a great part of its course it lies between the Mariposa and the Cape Horn slates. The schistosity is generally well marked, though schistose streaks may alternate with massive belts. The best exposures are found in the canyon of American River north of the toll house on the Forest Hill road. Numerous long and narrow slabs of clay slate are included in the amphibolite, as shown on the map. Under the microscope the less altered amphibolite shows plainly its derivation from igneous rocks of the type of augite-porphyrite or diabase-porphyrite. Under the influence of pressure the augites become converted into amphibole and the whole rock is filled by minute needles of the same mineral.

A number of small dike-like masses of similar amphibolite occur a mile or two west of Iowa Hill, others are near the head of Secret Canyon, and still others a mile west of Gold Run. The exposures are good only along the canyons; on the ridges deep soil is apt to mask the relations of the rocks. These altered igneous rocks certainly form dikes in the Carboniferous formations. Their relation to the Mariposa formation is less definitely ascertained. They may represent surface flows contemporaneous with the Juratrias slates, or they may form intrusive dikes in them. Both forms of eruption are known in connection with igneous masses in the Mariposa formation.

Greenstone-schists of North Bloomfield.

From the Middle Fork of the Yuba to the South Fork of Deer Creek extends an area of amphibolite-schist, lying between the Delhi formation and the Cape Horn slates. The rock, similar in appearance to other fine-grained amphibolites, shows in many places very plainly its derivation from diorites and diorite-porphyrites. A belt of nearly altered diorite lies in Bloody Run along the western contact. In the South Fork of the Yuba River are schistose rocks which in a very clear manner retain the porphyritic structure.

North of the Middle Fork of the Yuba the amphibolite is joined by a belt of serpentine which continues across Kanaka and Oregon creeks. In the canyon of the latter the serpentine incloses a belt of gabbro. All these rocks apparently form a dike intrusive in the Carboniferous series. Whether it represents one or several intrusions is uncertain.

The great serpentine belt.

Through the center of the Colfax quadrangle, from north to south, extends a broad belt of igneous rock surrounded by Carboniferous sedimentary rocks. It consists very largely of serpentine, from which feature the miners have called it the great serpentine belt. It is, however, a very complex area, made up of many basic rocks rich in magnesia, the most prominent of which are gabbro, peridotite and diorite. Partly serpentized peridotite has so often been found in the serpentine as to justify the belief that most of the latter rock has resulted from the alteration of peridotite, though it would perhaps be going too far to say that all of the serpentine had this origin. Large bodies of generally schistose amphibolite form parts of the belt and are probably all derived from gabbros and diorite; in many cases, however, it may be difficult to decide from what rock some amphibolites have been derived.

The great serpentine belt, extending through the Placerville, Colfax, and Downieville quadrangles, is apparently a continuous dike intruded in the Carboniferous sedimentary rocks, sometimes following, sometimes cutting across their strike. The primary rocks of which it consists are all granular; no porphyritic rocks are known to occur. At the southern boundary line the belt is narrow, consisting of serpentine and amphibolite, the latter schistose and of uncertain origin. The serpentine continues bending northeasterly up to Michigan Bluff, and its brown, rough outcrops are easily traced across Volcano and Mad canyons. Occasionally it contains smaller dikes of diorite. It is probably continuous below the lava ridge, as it again appears on the west side, here containing a large though ill-defined area of unaltered peridotite. The rock, however, is apt to contain a certain quantity of serpentine. The peridotite decomposes to a brown soil. Characteristic dark-brown, rough outcrops are frequently met with.

The western half of the belt here consists of amphibolitic rocks, generally schistose, and often of uncertain derivation. The schistosity is usually much better marked in the decomposed rock found along the ridges than in the fresh rock in the deeply incised canyons. In certain parts of this area the schists become chloritic and are sometimes difficult to distinguish from clay slate. Most of these obscure amphibolites are probably derived from diorites and possibly also from gabbros. The amphibolite narrows northward and, crossing the American River at the wild canyon known as Giant Gap, it runs out to a point before Bear River is reached.

A lenticular mass of gabbro adjoins the serpentine and the amphibolite in the vicinity of Dutch Flat. This gabbro is a dark-green rock consisting of pyroxene and greenish-gray feldspar, the latter usually having a flinty fracture and generally an altered aspect. In fact, the rock is a saussurite-gabbro, the feldspar being very largely converted to that fine-grained mixture of zoisite, epidote, albite, and other minerals called saussurite. The rock shows no schistosity. The main or eastern body of serpentine continues northward, crossing Bear River and Steep Hollow, and finally the South Fork of the Yuba at Washington. Partly altered rocks from this vicinity show the derivation of the serpentine from peridotite. North of the South Fork of the Yuba the serpentine is adjoined on the west by an amphibolite, a typical rock, fine grained and schistose, which branches into the sedimentary rocks below Washington. North of the lava ridge the belt continues, widening to 4 miles, the rocks being excellently exposed in the canyons of the Middle Fork of the Yuba River and Kanaka Creek. Between Alleghany and Orleans it consists of four lenticular comparatively narrow areas of serpentine, apparently having a steep easterly dip. Some of these areas may be of doubtful origin, but the one near the mouth of Wolf Creek is certainly derived from peridotite. From a point near Orleans the various belts are plainly visible across the canyon as light-green bands, almost void of vegetation compared to the brush-clad slopes of amphibolite and slate.

The main mass in this vicinity is a schistose amphibolite, ordinarily not very fine grained, consisting of brown hornblende in parallel crystals alternating with narrow streaks of greenish-gray, saussuritic feldspar. The origin of this amphibolite is very plain, at least along the canyon of the Middle Fork of the Yuba. Between Orleans and Snow Point a coarse gabbro, consisting of pyroxene, brown hornblende, and feldspar, outcrops in many places. All sorts of transitions between this gabbro and the amphibolite may be found. The schistose structure and the general rearrangement of minerals in the amphibolite are due simply to the pressure to which the gabbro has been subjected.

Along the road from Snow Point to Gold Canyon, as well as between Chips Flat and Alleghany, the amphibolites are very fine grained, fissile, and partly converted into chloritic schist. Some of these may even be difficult to distinguish in the field from clay slate. These chloritic schists are probably produced by the continuous action of pressure on the amphibolites.

Along Oregon Creek the serpentine belt consists of two streaks of serpentine inclosing a central mass of normal gabbro.

Dikes east of the serpentine belt.

The great mass of the Blue Canyon formation contains very few igneous rocks. Some small dikes of a dark-green, more or less schistose rock, well filled with pyrite, were noted. These are now amphibolitic and chloritic schists, probably derived from dioritic rocks. One of these dikes cuts across the slates at the point where the trail from Michigan Bluff to Big Oak Flat crosses the Middle Fork of the American River.

The granitic areas are usually remarkably free from dikes. Among the few noted are two narrow dikes of normal diabase crossing the road about a mile southwest of Bowman Lake. Small dikes of greenstone-schist and diorite-porphyrite occur along the trail from Cisco to Sterrett, as well as along the Sterrett quartz vein, in the hanging wall. The dikes near the granitic contacts will be mentioned later.

Diabase-porphyrite of English Mountain and vicinity.

English Mountain is a mass of diabase-porphyrite and diabase adjoined on the east and west by sediments of the Sailor Canyon formation. On the south it borders with sharp contact against intrusive granodiorite. The rock is dark green, medium to fine grained, and usually porphyritic by larger crystals of dark-green augite, frequently altered to uralite. Both diabase and diabase-porphyrite occur, the latter being most common. Excellent exposures are obtained in the bluff south of Jackson Lake. The porphyrite here is plainly shown as a surface eruption of heavy sheets, for it contains at frequent intervals fine-grained tuff—beautifully banded grayish and greenish rocks, flinty in appearance. The strata dip 25° E. and are thus conformable with the slates and limestones adjoining on the west. These latter often contain conglomerates, chiefly of chert and diabase-porphyrite, as well as minor intercalated masses of tuff similar to that of English Mountain.

A long dike-like mass of diabase-porphyrite adjoins the granite-porphyry east of Bowman Lake; and there is a smaller mass of the same material near Shotgun Lake. Whether these are intrusive dikes or intercalated flows is not certain.

The prominent peaks known as the Black Mountains, because of the contrast between their dark pinnacles and the brilliant white expanse of glaciated granodiorite, consist of a mass of coarse diabase-porphyrite. Northward this mass borders with sharp contact against granodiorite; southward, eastward, and westward it adjoins darker modifications of the same rock, and the contact is often difficult to locate with accuracy. At the westernmost of the peaks the relation of the rocks is obscure. The rock consists of an augitic modification of granodiorite, partly a greenish to brownish fine-grained malacolite-hornfels, evidently a contact metamorphosed sedimentary rock. The augitic granite near the summit of the peak is penetrated by a dike of uralite-porphyrite. The most plausible explanation of these occurrences is that we have here a fragment of Juratrias porphyrite and sedimentary rocks torn from their original position and engulfed in a mass of intrusive granitic rocks. The fact that the granitic rocks show such a complicated development of facies makes the relation difficult to interpret.

Sierra Buttes, English Mountain, the Fordyce area, and Snow Mountain probably once formed a continuous mass of Juratrias eruptions intercalated in the sedimentary series. Its continuity has been broken by the intrusion of granodiorite.

Area between North and South forks of the Yuba.

Granite.—A lenticular area from 3 to 5 miles wide and about 18 miles long, inclosed by the slates, extends from the South Fork of the Yuba up to the ridge overlooking the North Fork of the Yuba in the Downieville quadrangle. This area is occupied by a coarse-grained granite, very constant in its texture and composition. It resists disintegration strongly and forms a number of high, rough ridges separated by deeply trenched canyons. Its color is light gray, and it consists of white feldspar and large crystals of gray quartz, together with a small amount of hornblende or biotite, or both. Its structure distinguishes it clearly from the granodiorite. It is much more acidic, and the quartz, instead of being pressed in between the feldspars, forms large isolated grains. The scarcity of ferromagnesian silicates also distinguishes it from granodiorite. The feldspars, plagioclase as well as orthoclase and albite, are nearly always greatly decomposed, so that their character can rarely be established in thin section. The rock is rich in soda and may be designated as a soda-granite.

Basic modifications richer in iron and magnesia occasionally occur in smaller masses, sometimes brecciated by acidic normal rock; thus, for instance, on the trail from the California mine to the Baltic a facies rich in pyroxene occurs. Dioritic modifications were noted on the Milton ditch, 4 miles northeast of Graniteville.

In the eastern part of the quadrangle, especially in the vicinity of Bowman Lake, the rock changes to granite-porphyry similar to that in the long dike east of Bowman Lake, and the adjoining slate contains dikes of the same material. Though this granite area is beyond doubt intrusive into the slates, it should be noted that the contact metamorphism of the slates is far less noticeable than along the contact of the main granite area. Immediately at the contact the clay slates become crystalline, and appear as knotty schists for some little distance away from the contacts.

Granodiorite (with dioritic and gabbroitic modifications).—The granitic rocks of the high sierra project at two places into this quadrangle. The northerly area occupies about 65 square miles between English Mountain and Monumental Hill. It extends under the lavas to the northeastern corner of the quadrangle, sends a long bay into the slate area between Emigrant Gap and Cisco, and contains near the latter place a projecting spur of the Sailor Canyon formation.

The principal rock is a normal granodiorite of light-gray color and medium-grained texture. Its constituents are, as usual, white feldspar, dark-green hornblende, black biotite, and some gray quartz. Near the contacts it is very common to find the ferromagnesian silicates increasing in quantity, changing the rock to a diorite or quartz-diorite. This is not, however, an invariable rule, for at many places the normal rock, or a rock even more acidic, borders directly against the slates. Over two areas the granodiorite presents interesting modifications connected by gradual transitions. From Grouse Ridge to Summit City and thence toward English Mountain extends a broad belt in which a diorite, augite-diorite, or even locally a gabbro takes the place of the granodiorite. All these rock types are connected by numberless transitions, so that it is impossible to draw distinct contact lines. From a prominent point this belt of darker basic rocks is clearly discernible on the wide extent of glaciated surfaces.

Area from Grouse Ridge to Summit City and English Mountain.

Southeast of English Mountain, and on both sides of French Lake, a peculiar rock, consisting of augite, plagioclase, and much quartz, occurs. This is again connected with the granodiorite by numberless transitions, and again, on the other hand, is not always sharply separated from the darker diorites. This augite-diorite has a bright, brilliant white color, distinguishing it from the somewhat darker-gray granodiorite.

Area between Signal Peak and Emigrant Gap.

The deep bay extending into the slates between Signal Peak and Emigrant Gap is in many respects interesting. South of a line drawn from Langs to Crystal Lake it is filled by gabbros or allied rocks. Again, there is no contact but only a gradual transition between this gabbro and the normal granodiorite, caused by gradually increasing quartz and orthoclase. Toward the south the gabbro becomes more and more basic, and finally, over a somewhat indefinite area about a quarter of a mile wide and 3 miles long, the gabbro changes to a normal peridotite. The gabbros are coarse-grained dark rocks, often weathering to a brown color. The peridotite is a dark yellowish-gray, granular rock weathering to a deep yellowish-brown. In the immediate vicinity of Monumental Hill are abundant transitions between the two rocks. The area of peridotite is not well exposed, being partly covered by morainal detritus.

To the northwest of Cisco a small area of pyroxenite changing into gabbro adjoins the contacts, while a little farther south, on Cisco Butte, the same contact is adjoined by acid quartz-diorites peculiarly admixed with streaks of darker rocks.

The peculiar metamorphism of the slates is always strongly marked, especially in the projecting area of Signal Peak. Dikes are very common along certain parts of the contacts. Those of granodiorite are relatively rare, but occur on the hill west of Faucherie Lake. Dikes of diorite occur near Fall Creek Mountain. From here down to Emigrant Gap dikes of granite-porphyry with large feldspar crystals are very common. Similar dikes occur in abundance on Signal Peak, accompanied by some of diorite-porphyrite containing large crystals of feldspar in a dark-green groundmass. Pegmatite dikes are less common, though some were noted in the granite on the ridge extending east of Signal Peak. Tourmaline sometimes occurs in these.

In the Sailor Canyon formation south of Cisco there are occasional dikes of diorite or diorite-porphyrite which may be connected with the granitic eruption.

The other projecting spur from the main granite area is found in Long Canyon Basin, in the southeastern corner of the quadrangle. The rock is a normal granodiorite and the slates at the contact show strong contact metamorphism.

SEQUENCE OF ROCKS AND STRUCTURAL FEATURES OF THE BED-ROCK SERIES.

The stratigraphy of the Sierra Nevada has long been known to present great difficulties, and it is to be regretted that this examination has not been sufficiently detailed to thoroughly elucidate the subject. There are, however, many obstacles to its explanation, not the least being the fact that the bedding often can not be made out and that, owing to decomposition and sliding soil, dips or strikes, except those taken along the courses of canyons, are rarely reliable.

Compression and folding of Calaveras formation.

The oldest rocks of the Colfax quadrangle are probably Carboniferous, though the possibility of the occurrence of a still older Paleozoic series is not denied. The relative age of the subdivisions of the Paleozoic (Calaveras) series has not been established; they have the appearance of one conformable series, the thickness of which it is difficult, if not impossible, to determine with accuracy. After the deposition of the Calaveras formation and before the deposition of the Juratrias the Paleozoic series was closely folded and compressed, though probably not to such an extent as now, and a schistosity having a general north-northwest direction and a steep easterly dip was superimposed. All this, augmented by a still later compression, has made the interpretation of the stratigraphy exceedingly difficult. It was formerly supposed that the Carboniferous rocks consisted of one indefinitely repeated series. The five distinct lithologic divisions shown to exist limit the repetitions considerably, though, for instance, in the Blue Canyon formation, there is still ample room for them. On the whole the Calaveras beds should perhaps be regarded as thrown into many sharply compressed folds, nearly vertical or slightly overturned eastward. The upper parts of these folds are eroded; the lower parts are rarely exposed; so that as a rule only the nearly parallel, steep flanks of the folds are accessible to observation. Attention should be called to the interesting fact that near Washington the ordinary dip of bedding and schistosity is reversed over a width of about 5 miles, and a length of probably 12 or 15 miles.

Juratrias deposition.

The Sailor Canyon and the Mariposa formations were without doubt deposited unconformably on the upturned Calaveras formation. Among the evidences of this are less steep dips, conglomerates of older formations, and a much less degree of schistosity. Whether an unconformity again separated the Sailor Canyon from the younger Mariposa formation is not certain.

Mountain building and eruptions of igneous rocks.

After the deposition of the Juratrias a mountain-building disturbance followed, during which the later beds were folded against the Carboniferous land masses and considerably compressed. During the latest Juratrias or earliest Cretaceous the great eruptions of igneous rocks occurred. Some of them, as, for instance, the diabase of English Mountain, certainly were poured out during the deposition of the Juratrias, but the granitic rocks were intruded somewhat later.

Relative age of igneous rocks.

A general sequence of rocks can not be said to have been established. The general rule holds good, however, that the main granitic area is more recent than the greenstones and serpentines, and that in a given area of granular rocks the darker modifications are nearly always older than the lighter-colored acidic facies. Near Colfax the gabbro is clearly intrusive into the augite-porphyrite of the Mariposa formation. As to the age of the Canyon Creek granite, nothing definite can be said. It contains near Bowman Lake some dikes of diabase which may or may not be contemporaneous with that of English Mountain. At any rate it is possible that this granite area is older than the main mass of granitic rocks of the Sierra Nevada. Nothing definite can be said as to the relative age of the rocks of the great serpentine belt.

Dip of joint planes.

The Bed-rock series is more or less affected by jointing, but in this quadrangle the jointing is nowhere so regular and intense as in the granites south of Lake Tahoe. The diabase of English Mountain is in places cut by fissure systems striking nearly east to west and dipping steeply north. The joints in the granite at the east end of English Mountain dip from 23° to 55° NW., being from a few inches to a foot apart. In the granite near Faucherie dam the joints dip 70° S. On the road from Meadow Lake to Jackson steep easterly dips of the joints were noted. Great joint planes having a northwesterly direction also cut through Old Man Mountain. It is thus seen that no great regularity obtains.

The intrusions of igneous rocks exerted in places so great a pressure on the slates that the latter were displaced and bent to an extraordinary degree. Thus the sudden widening of the serpentine belt at Michigan Bluff caused a strong northeasterly strike of the adjoining slates for several miles. South of Monumental Hill the disturbance in the slates caused by the granitic intrusions is especially noticeable. The strike along Monumental Creek is from east to west and the effects of violent intrusion probably extended as far down as the North Fork of the American River, to judge from the greatly varying strikes and dips and the frequent east-west schistosity. While the pressure of the intruding granitic rocks may in places have caused some schistosity in the adjoining slates, it has done so only to a limited degree. The intrusion often followed the line of strike, as the rocks were most easily fractured along that direction, but sometimes the fractures took place across the strike and dip. In such places the slates are usually greatly disturbed and filled with injected igneous material.

Effect of intrusions.

SUPERJACENT SERIES.

Under this heading are described the Neocene and Pleistocene sedimentary rocks and lava flows, as well as the surficial accumulations due to the glaciation of the range.

NEOCENE PERIOD.

Auriferous gravels.—The Auriferous gravels comprise the gravels, sands, and clays deposited in the valleys of the Neocene river system. These sediments occupy larger areas in this quadrangle than in any other part of the Gold Belt. The causes of this great development will be explained later on. Many of the gravel bodies are exposed by erosion; very large amounts remain covered by andesitic tuff masses to a depth of many hundred feet; still larger masses were completely removed during the Pleistocene process of canyon cutting.

General relations.

The Auriferous gravels proper may be divided into (1) the deep gravels, (2) the bench gravels, (3) the gravels of the rhyolitic epoch, (4) the gravels of the intervolcanic erosion epoch, and (5) the gravels of the andesitic tuff.

Deep gravels.

The deep gravels consist of well-rounded cobbles and pebbles of the Bed-rock series cemented by sandy material. They are generally coarse and compact, and large waterworn bowlders sometimes occur near the bottom of the channel. They fill the deepest, trough-shaped depressions to a maximum depth of 200 feet—frequently, however, much less. They are usually rich in placer gold, especially near the bed rock.

Bench gravels.

Bench gravels cover the deep gravels to a maximum depth of 300 feet and are spread out on the sloping floors often to a width of 2 or 3 miles, extending on both sides of the deepest trough. They often contain a predominating amount of quartz pebbles, but no andesite or rhyolite. They are less compact and generally less coarse than the deep gravels. Interstratified with them, and especially covering them, are in many places heavy masses of light-colored sand and clay. The bench gravels all contain gold, though less than the deep gravels.

Gravels among volcanic masses.

The volcanic rocks covering the Auriferous gravels occasionally contain interstratified gravel masses, which may be auriferous. The latter do not strictly belong to the Auriferous gravels but are sometimes difficult to distinguish from these and are partly described with them. They may be classified as gravels of the rhyolitic epoch, gravels of the intervolcanic erosion epoch, and gravels of the andesitic tuffs.

Gravels of the rhyolitic epoch.

The rhyolitic flows dammed many lateral streams, causing immediate accumulations of gravels, clay, and sand. During the intervals between rhyolitic eruptions the streams cut down new channels in the soft material, and masses of gravel were deposited in their beds. These interbedded gravels are called gravels of the rhyolitic epoch. Occasionally they may attain a thickness of several hundred feet. They range from coarse to fine, and are similar in character and composition to the bench gravels, but usually contain many rhyolite pebbles. The quartz pebbles are also fewer in number.

Gravels of the intervolcanic erosion epoch.

The interval separating the rhyolitic from the andesitic outbursts apparently differed in length at various points in the Sierra Nevada. While in some places, as along the lower courses of the Middle Fork and the South Fork of the Yuba, the andesitic tuffs lie almost conformably upon the rhyolitic tuff, there are at other points, as on the Forest Hill divide, indications of a relatively short period of very active erosion, beginning immediately after the rhyolitic flows, or in some places soon after the first flows of andesitic tuffs. This erosion was of a remarkably intense character, incising sharp V-shaped canyons in new channels through the older beds, and in some places cutting down into the solid bed rock to a depth of about 100 feet. This action is so very different from that of the ante-rhyolitic and rhyolitic streams that the inference is justified that just after the rhyolitic flows the tilting of the slope of the Sierra Nevada took place, or at least began. In the bottom of these sharply cut channels a few feet of gravel accumulated along stretches with less grade, while where the gorges were narrow and the grade was steep no detritus is found. These are the gravels of the intervolcanic erosion epoch. The gravels contain pebbles of the Bed-rock series and of andesite and rhyolite. They contain less quartz than the bench gravels but are frequently very rich in gold.

Gravels of the andesitic tuffs.

The gravels intercalated among the andesitic tuffs and breccias consist as a rule of andesitic pebbles mixed with a few pebbles of quartz or other older rocks. They are rarely auriferous and most of them are entirely barren.

Neocene topography.

The most casual examination of the Auriferous gravels reveals the fact that they are deposited on an irregular surface mostly high above the present drainage lines. More careful examination soon shows that the gravels lie chiefly in depressions—some narrow and deep, others broad and shallow—the deepest lines of which form channels continuous until interrupted by the trenches of the modern canyons. The principal channel fragments on the different ridges have generally such elevations that they might have once been connected so as to form one continuous gravel-filled stream bed with grades similar to those of ordinary water courses. Between these channels the Bed-rock formation rises often to considerable elevations. Finally, the examination of the whole range shows a great system of channels, all sinking toward the Sacramento and San Joaquin valleys, becoming larger and broader in that direction, whereas eastward they branch into smaller channels, showing near the summit of the range every indication of proximity to a watershed. The fluviatile origin of the gravel channels and the general disposition of these ancient rivers are not theories; they are facts convincingly and completely proved.

The remarkable absence of faults over the western slope has been a great aid in the interpretation of the gravel channels. Only in very few places have disturbances been found which developed later than the Neocene period.

The help of a contour map is almost indispensable to enable one to obtain a correct idea of the Neocene drainage topography. Each point of the contact lines between the bed rock and the superjacent Neocene gravels or volcanic flows necessarily marks a point on the old surface of the region such as it was before being hidden under Tertiary accumulations. A great number of these contact lines are usually exposed by the canyons and creeks eroded since the close of the Neocene period, and each of them affords a section through a part of the Neocene surface. It will easily be seen that if the elevation of a sufficient number of points on the contact lines were known, a contour map showing the relief of the Neocene surface might be constructed. If no change in altitude had taken place in the interval this map would show the relation to the Neocene sea level, and this relation may be made out if the amount of disturbance which the old surface has suffered can be ascertained by other means.

The areas of bed rock that have been above the surface of the lava flows since the end of the Neocene—and there are many of them in the Gold Belt region—have often suffered a degradation difficult to measure, but probably in most cases not large. The flat tops of many of them are surviving parts of the Neocene surface, and erosion, while scoring and furrowing their flanks, has not yet materially lowered their summits. Many of the topographic features of the Neocene surface may be directly read on the contour maps on which the geologic areas are outlined. If in a certain vicinity the contact lines between lava and bed rock run practically parallel with the contours of the present surface, that is, horizontally, it is apparent that the Neocene deposit rests on a surface that is now horizontal and may have had the same altitude in Neocene time, provided no tilting has taken place since. If, however, the contact lines cross the contour lines in an irregular way and at considerable angles, the old surface was broken and irregular. Even then, with a sufficient number of contacts, the general drainage system may be made out. In the case of an old valley running across a recent creek or canyon, the angles of the contact lines with the contour lines on the opposites sides of the present gorge indicate the ancient trough.

The relief of the Neocene surface was of an undulating, hilly character. The slopes lay at angles up to 10° and the rounded ridges rose to heights varying from a few hundred to 1500 feet above the channels. In the eastern part of the quadrangle somewhat different conditions obtained. Here the Neocene topography was decidedly more abrupt. A number of prominent, flat-topped hills rose to a height of 2000 feet above the water courses. Among them are English Mountain, Signal Peak, Monumental Hill, and Duncan Peak. There are practically no auriferous gravels in this upper region, embracing the eastern third of the quadrangle. Evidently the rivers in this region were able to transport easily all the material received by them.

The outlines of early Neocene drainage were as follows, the connections in most cases being established with considerable certainty. In general the drainage was partly transverse, flowing down the range like the present system of rivers, but in part it was also parallel to the present range, taking a course followed by none of the present rivers, and clearly indicating a low range with longitudinal ridges. It is believed now that the whole of the Neocene drainage in this quadrangle found an outlet in the important master stream which extended from North Columbia down to Smartsville, and to the waters of the Neocene gulf occupying Sacramento Valley (see Geologic Folio No. 18). This principal stream broke across the longitudinal ridges of Jurassic eruptives in a relatively deep and narrow valley.

Near North Columbia the main trunk channel branched. The northerly channel continued eastward to North Bloomfield; there it turned north and then east, following nearly the present canyon of the Middle Fork to Moores Flat and Snow Point. Then, crossing the present canyon, it entered the Downieville quadrangle northeast of American Hill; curving south one of the branches entered this quadrangle again near Findley Peak, heading in the region between Meadow Lake and Castle Peak. A tributary to this channel followed in part the present Oregon Creek and joined it in the Smartsville quadrangle. Still another tributary ran by the way of Derbec mine, Relief, Alpha, Omega, and Bear Valley.

The very important southerly branch of the trunk channel followed from North Columbia to Little York a broad longitudinal valley having a south-southeast direction, and bordered on the west by a high ridge of diabase and slate. At Little York the channel again bent sharply northeast to Dutch Flat and tributary branches extended up to Alta, Lowell Hill, and Shady Run.

On the Forest Hill divide important channel systems have also been traced, but it was formerly believed that these found their outlet directly southwest toward the Great Valley. Later investigations, however, seem to indicate that this great channel system connected with that north of the watershed of the American River. In spite of various difficulties, explained more in detail below, it now seems probable that the longitudinal valley continued in the same general direction to Yankee Jim and that the channel ran by way of Dutch Flat, Indiana Hill, Iowa Hill, and Wisconsin Hill; further that it turned easterly near Forest Hill and continued by way of Mayflower, Bath, and Michigan Bluff, thence across the Middle Fork of the American River to the Long Canyon divide. From here there is no doubt about its upper course. After a short bend southward extending into the Placerville quadrangle it cut across the extreme southeast corner of Colfax quadrangle, then continued in Truckee quadrangle up by French Meadows and Soda Springs to its former headwaters south of Castle Peak. This important stream was joined by tributaries, the principal one coming down from Damascus to Michigan Bluff. This was again joined by lesser streams from Secret Canyon and Red Point and from Last Chance and Deadwood.

During the later part of the Auriferous gravels epoch the topographic conditions were materially different. The lower valleys were filled with gravel to a depth of several hundred feet, and the streams meandered over flood plains which locally attained a width of 3 miles. They became less able to carry the load of detritus, and deposits of clays and sands increased greatly. Low divides were covered and many streams were diverted from their original channels. This phase became even more pronounced when, as a result of the rhyolitic eruptions in the high sierra, vast masses of ash and fine volcanic detritus were piled up in the river channels. Overloading and deposition ceased only after the close of the rhyolitic eruptions or during the beginning of the andesitic eruptions, when an uplift or westward tilting of the surface took place. The grade of the rivers being increased, cutting immediately followed and proceeded, in some regions, especially on the Forest Hill divide, to such an extent that new channels were excavated in the old river valleys without reference to the older courses, as narrow, steep-sided gorges cut into the soft sediments and even into the underlying hard Bed-rock series. A small amount of gravel accumulated in places along these intervolcanic channels, and such deposits are frequently rich in gold reconcentrated from the older gravels. The streams of these channels were evidently able to transport the great quantity of material offered to them. Channels of this kind rarely occur in the northern and central part of the quadrangle. They have been noted, however, north of Forest, and are especially prominent in the Ruby drift mine (Downieville quadrangle). One is also said to have been met with in drifting below the lava capping northeast of American Hill. In the higher range the valleys were narrow and contained little detritus. The intervolcanic streams simply reexcavated or deepened these without creating new channels. But on the Forest Hill divide and in the adjoining region the old deposits are repeatedly cut by intervolcanic channels, of which two epochs may be recognized. Below Forest Hill these did not follow the old drainage lines but established new courses directly down the slope of the range by way of Peckham Hill (Placerville quadrangle). The interval between the rhyolites and the final andesitic eruptions must have been much longer here than farther north.

Intervolcanic streams.

Fossils in the Auriferous gravels.

The fossils thus far found in the Auriferous gravels consist chiefly of impressions of leaves and of silicified and carbonized wood. Such impressions are found almost everywhere in the upper bench gravels and in the clays of the gravels of the rhyolitic epoch, as well as in those overlying the intervolcanic channels. The oldest, deep gravels contain no fossils. Fine collections have been obtained from the base of Chalk Bluff at You Bet from a stratum of clay contained in the upper part of the bench gravels below the rhyolite; also in the same position at Independence Hill 1½ miles northeast of Iowa Hill. In the Weske channel a number of trees have been found standing on the bank of the gravel deposit, with the roots intact in the soil and bed rock. One of these, similar to a cedar, is 100 feet in length and 4 feet in diameter, standing upright in the andesitic tuff, here covering the bed rock. Similar standing trees are also found in the Bowen mine, in the same channel. Again, at the Reed mine, near Deadwood, standing trees have been found, none of them being much over a foot in diameter.

The flora has a semitropical aspect, similar to that of the Gulf States. The following conclusions are drawn from its character: The deep gravels are probably of Eocene or Eomiocene age. The bench gravels and the rhyolitic tuffs are probably of late Miocene age. The age of the gravels of the intervolcanic erosion epoch and of the andesitic tuff is not established beyond doubt, but these probably belong to the early Pliocene or late Miocene. The eroded surface upon which the Auriferous gravels were deposited was consequently produced either during the earliest Miocene or during the Eocene.

Age of the gravels.

Study of the grades of the Neocene channels in this quadrangle shows that most of them have at present grades as steep as 150 feet per mile, much steeper than any which could reasonably be expected in a region of comparatively gentle configuration. Almost the only exceptions are found among those principal water courses which had a northwest or north-northwest direction. These have very slight grade. Most prominent among these is the Neocene South Fork of Yuba, which from You Bet to North Columbia has an average grade of less than 17 feet per mile. From this the conclusion has been drawn that the grade has been increased considerably by a tilting movement of the range as a whole, which would add to the grades of all rivers flowing in a general westerly direction, while it would affect rivers running parallel to the range but little. This tilting apparently took place or began shortly after the close of the rhyolitic eruptions. For detailed discussion of the Neocene river channels and the auriferous gravels contained in them, the reader is referred to the description under the heading "Economic geology."

Grades of Neocene rivers.

Rhyolite.—Toward the end of the Neocene the period of volcanic activity began. The first eruptions consisted mainly of rhyolite and its tuffs. These rocks do not occupy very large areas but are rather widely distributed. Resting upon gravel or rocks of the Bed-rock series they are covered by later andesitic eruptions and are exposed only where erosion has cut through the volcanic masses. The massive rhyolite is a light-gray or pink, fine-grained, and compact rock, easily dressed and often showing small porphyritic crystals of quartz and sanidine. Its outcrops frequently form abrupt cliffs or bluffs. This rock occurs chiefly in the eastern portion of the quadrangle, typical exposures being those northwest of English Mountain, Sugarpine Flat, and Canada Hill. The vent from which the rhyolite of English Mountain poured out was located near Castle Peak or Mount Lola, at the summit of the range, while the sources of the other two eruptions are not definitely located.

In the western part of the quadrangle the rhyolitic rocks consist chiefly of tuffs, sandy or clayey, of brilliant-white color and generally easily showing their origin upon microscopic examination. The rhyolite flows, being of moderate volume, closely followed the courses of the Neocene valleys and are therefore good indicators of the lowest depressions in the old surface. The massive flows, probably being viscous, did not extend far from their sources, but the tuffs continued much farther. These tuffs were evidently carried down by the streams as mud flows, deriving their contents from masses of volcanic ash accumulated near the vent. It often happens that the Auriferous gravels are covered by extensive light-colored, fine-grained, sandy or clayey beds, usually called pipe clay. In many cases, for instance, at Moores Flat, Omega, North Bloomfield, and North Columbia, the origin of these is uncertain. Probably all of them contain volcanic material, but they hardly can be considered as volcanic tuffs. Granitic sand is certainly an important constituent of many of them. They have been mapped with the Auriferous gravels.

In the northwestern part of the quadrangle no rhyolitic tuffs have been found, although bowlders of rhyolite sometimes occur in the breccias. A little rhyolite appears below the andesite at the hydraulic cut just north of Graniteville.

A once continuous flow of rhyolitic tuff can be traced along the course of the Neocene South Fork of the Yuba, beginning east of Blue Canyon and extending down by Alta, You Bet, Quaker Hill, and Scotts Flat. Some of the first outcrops northeast of Towle consist of massive light-colored rhyolite, but below this nothing but rhyolitic tuffs of very sandy to clayey texture and brilliant-white color can be observed. This tuff crops extensively in the vicinity of Alta, here attaining a thickness of over 300 feet, but it is to a great extent covered by red soil washed down from the overlying decomposed andesite. The flow once filled nearly the whole of the broad river valley and even overflowed the adjoining ridges in one or two places. At Iowa Hill, Independence Hill, and Monona Flat a thin stratum of rhyolitic tuff appears below the andesite, which probably found its way here from the vicinity of Alta. From Dutch Flat to You Bet the rhyolite as well as the overlying andesite is eroded. It appears, however, at Chalk Bluff, so named from the brilliant white color of its exposures. Here from 100 to 200 feet of rhyolitic tuffs underlie the andesite. Similar exposures are found at Quaker Hill, Hunts Hill, and Buckeye Hill. In the vicinity of Quaker Hill especially the relations are interesting, as Deer Creek has cut through the whole Neocene river valley, affording an excellent section. The main fork of the Neocene South Fork of the Yuba doubtless continued northward across the present South Fork of Yuba River near Blue Tent, but as in this vicinity a low divide separated this basin from that of Nevada City much of the rhyolitic tuff overflowed this low divide and found its way to the Nevada City Basin. At Blue Tent the gravels are overlain by about 200 feet of light-colored sands, but their rhyolitic character is not plainly indicated, and it is probable that the small amount of tuff remaining in the old river valley after the overflow toward Nevada City had taken place was greatly mixed with sands and clays of local origin and thus rendered conspicuous.

One of the largest eruptions of rhyolite in the Sierra Nevada took place near Castle Peak in the Truckee quadrangle. The molten rock followed the course of the Neocene American River along the present Middle Fork. It enters this quadrangle near the southeastern corner, where it nearly fills the broad, flat Neocene valley, and is excellently exposed along the slope to the north of Long Canyon. Some massive rhyolite is met with at the eastern boundary, but below this nothing but white tuffs occur. The thickness of the rhyolite, which often forms bluff-like outcrops and contains intercalated bodies of gravel, is here from 400 to 600 feet. Excellent exposures are found near the Ralston mine. A fragment of the same channel is seen near Michigan Bluff, and at the base of Sugar Loaf near that town a little rhyolite is exposed. The same channel appears again at Bath and Mayflower, passing thence southward under the lava cover near Forest Hill. At Bath and Mayflower somewhat over 100 feet of rhyolitic tuff and intercalated gravels are exposed. At Forest Hill, along the bluff south of the town, the thickness exposed is from 40 to 130 feet.

About a mile northeast of Sugarpine mill a small amount of exceedingly fine-grained chalk-like rhyolitic tuff crops below the andesite.

Andesite.—After a considerable interval, during which the rhyolite lavas were much eroded, the volcanoes along the summit of the range began to pour out masses of the moderately basic lava known as andesite. During the rapidly succeeding eruptions andesitic material from these volcanoes was spread over the whole western slope of the Sierra Nevada. Practically the whole of Colfax quadrangle was, after the close of the eruption, covered by an andesitic mass to a depth of from a few hundred to over a thousand feet, the greater thickness being found in the northeastern and southeastern portions. Only a few points remained like islands above the surface of the vast lava masses. Among these are English Mountain, the Black Mountains, and Signal Peak; probably also Duncan Peak, as well as some ridges to the west of Duncan Canyon. The whole western part was submerged with the possible exception of Banner Hill. Pleistocene erosion has removed the larger part of the volcanic covering. Enough remains, however, to cap the summit of nearly every important ridge to a depth of a few hundred feet. The andesitic rocks rest on rhyolite, gravel, or the older formations of the Bed-rock series. As a rule the greatest depth is along the old channels, while the adjacent bed-rock hills may have been only superficially covered. Throughout the whole area the andesitic rocks are of a fragmental character. They consist, as seen in good exposures, of strata ranging in thickness from a few feet upward. By far the most usual form is a tuff breccia consisting of angular or subangular fragments of andesite cemented by a dark-gray material chiefly consisting of finely ground-up andesite. The lower part of the beds frequently consists, especially in the western part of the quadrangle, of volcanic sands, clays, and fine-grained tuffs. Intercalated between these, and always covering them, are strata of the above described tuff breccia. In the lower part of the series may occasionally be found smaller masses of a mixed gravel of quartz and metamorphic rocks. The tuff breccia contains exceedingly little nonandesitic material. Occasionally scattered granite bowlders are included, as near American Hill and other places. This granite is identical with that occurring near the summit of the range. Pebbles of granite and metamorphic rocks are of rare occurrence in the tuff breccia. The andesite, as shown in the included bowlders, which frequently reach a size of 3 feet or more in diameter, is a rough and porous rock of dark-gray to dark-brown color. Porphyritic crystals of plagioclase feldspar are invariably present, as are also crystals of augite and hypersthene. Hornblende is less abundant, but appears in many rocks as small, black, glistening needles. Biotite is of very rare occurrence. The groundmass in which these crystals are embedded has a structure varying from glassy to very fine-grained microcrystalline. While the structure of the tuff breccia is similar throughout the quadrangle, there appears to be a slight difference in that to the north and south of the North Fork of the American River. North of this stream the andesite bowlders in the breccia consist to a considerable extent of hornblende-andesite, all, however, carrying also some pyroxene. The rocks have in general a grayish or brownish color. Besides these hornblende-andesites there are a large quantity of ordinary pyroxene-andesites. On the Forest Hill divide the andesites appear darker in color and the pyroxenic rocks predominate.

The volcanoes which ejected these enormous volcanic masses were located along the crest line of the range. North of the watershed of the American River the andesites originated from the volcanoes of Webber Lake, Mount Lola and Castle Peak. South of that line they were poured out from the volcanic vents south of Tinker Knob (Truckee quadrangle), the lavas of which were of a predominatingly pyroxenic character. It is believed that these andesitic tuffs were largely carried down the slope, following the old river valleys as volcanic mud mixed with water. This mud consolidated or set like a hydraulic cement to a hard, compact mass. Probably, however, dust showers from the volcanoes produced some of the material, while other masses, especially near the base of the series, may have been worked over by the streams in the interval of volcanic eruptions.

The only occurrence of massive andesite that flowed down as a molten mass is found 2 miles southwest of Cisco at the head of Lake Valley, though flows similar to this are noted in the adjoining Truckee quadrangle. At this place a small bed 20 or 40 feet thick appears at the base of a tuff breccia. It is an olivine-pyroxene-andesite with large, clear feldspar crystals and dense, black groundmass, similar to the rock from Table Mountain, Tuolumne County, but it does not contain as much potash as that rock.

The surface of the lava flows, generally of a rolling or level character, is often decomposed to a considerable depth, and the dark-red clay soil generally contains unaltered bowlders from the tuff breccia embedded in it. A few notes on the exposures at various places follow below.

Normal tuff breccia covers the larger part of the ridges in Sierra County. Near Plum Valley, however, fine-grained tuffs without bowlders were noted. Good exposures are seen near Cold Spring and Alleghany. The heavy masses northeast of English Mountain, as well as those east of Graniteville, consist of very imperfectly stratified tuff breccias. The outcrops in the glaciated areas are generally very good. Similar in character is the andesite from the North Bloomfield ridge, although here fine-grained tuffs begin to appear in the lower portion and coarse volcanic conglomerates are occasionally noted embedded in the tuff breccia. Good exposures may be seen at Relief Hill, along the beach above Orleans at Backbone House, and near North Bloomfield. The andesite tuff on the ridges extending from Cisco down toward Nevada City calls for no special comment. Good exposures are rare but sometimes occur near the head of steep ravines where landslides have occurred. At Bowman Valley where the andesite is over a thousand feet thick, the glaciated bluff presents excellent exposures.

The small areas in the southwestern part of the quadrangle near Colfax present no unusual features. A stratum of tuff breccia is always present; occasionally, also, underlying strata of finer tuffs.

The Long Canyon divide and the upper part of the Forest Hill divide present no unusual features as far as the andesitic rocks are concerned. The lower southwestern part of the quadrangle is characterized by a great abundance of volcanic sands and tuffs alternating with tuff breccia, and occasionally containing smaller bodies of gravel, sometimes auriferous. This is probably explained by the fact that a broad river basin existed in this vicinity in which the volcanic material was frequently worked over between the eruptions. The channels of the intervolcanic epoch, which contain little or no gravel, are usually found to be completely filled with tuff breccia. Here, as well as in other parts of the quadrangle, the last and heaviest flows consist of the same tuff breccia.

The following sections show accurately the composition of the lava cap covering the gravel at various points on the Forest Hill divide. They have been obtained chiefly in shafts sunk through the volcanic cap to reach the underlying gold-bearing gravels.

Sections of andesitic flows.

Section near Gray Eagle shaft.

	Feet.
Andesitic tuff breccia	130
River wash, sand, and gravel, largely volcanic	110
Andesitic tuff	60
Gravel and sand	10
Andesitic tuff	20
Gravel	7
Andesitic tuff	25
Gravel	2
Bed rock.	
Total	364

At this place there are thus four distinct strata of volcanic material separated by four strata containing river wash. Of course most of the pebbles in this are volcanic, but most of them contain a little gold.

Section north of New York Canyon, near Iowa Hill.

	Feet.
Andesitic tuff breccia	90
Auriferous gravel	4
Andesitic tuff	160
Auriferous gravel	60
Bed rock.	
Total	314

Section at Reed mine, Deadwood.

	Feet.
Andesitic tuff breccia	70
Gravel with a little gold	7
Andesitic tuff	40
Gravel	6
Andesitic tuff	30
Brown tuffaceous clay ("chocolate")	5
Auriferous gravel	3
Bed rock.	
Total	161

This section is characteristic for a considerable extent of country in the vicinity of Eldorado Canyon, Deadwood, and Last Chance.

PLEISTOCENE PERIOD.

The Pleistocene period as defined in this folio may be divided into three epochs:

1. The epoch of elevation and erosion, beginning with the close of the andesitic eruption and the great uplift of the Sierra Nevada. This is by far the longest of the three. During this epoch the great canyons were excavated to practically their present depth. The waterlaid deposits accumulated during this time are naturally insignificant and consist mainly of small gravel benches left along the canyon slopes at points somewhat protected from erosion.

2. The Glacial epoch, which began only after the canyons had been eroded almost to their present depth and which occupied a lesser interval of time. Its deposits are abundant and consist partly of moraines and other glacial detritus, partly of low gravel bars along the rivers, below the limit of glaciation.

3. The post-Glacial epoch, continuing up to the present time. This has occupied a very short time, comparatively speaking—in fact, probably only a few thousand years. The deposits belonging to this epoch are insignificant, consisting of gravels in the present stream beds and sands and silts in small glacial lake basins.

The only distinction attempted on the map is between moraines and glacial drift on one hand and river gravels on the other.

Fluviatile gravels of pre-Glacial age.—These small gravel areas are remains of the old river deposits accumulated during the gradual process of canyon cutting, and most of them are only from 25 to 100 feet above the present river level.

Only rarely, as south of Michigan Bluff and at Hayden Hill, south of Towle, are benches from 200 to 600 feet above the river level preserved. Many of these areas of Pleistocene gravel are found along the Middle Fork of the Yuba, but they are seldom more than a few acres in extent. They are even more common along the South Fork of Yuba River, especially from Washington westward. A short distance east of Washington is a more extensive gravel deposit, reaching as far as the mouth of Scotchman Creek. These gravels are composed in part of very large and subangular fragments, and may be partly of glacial origin. They have, however, certainly been concentrated by fluviatile action. Their thickness is from 10 to 30 feet.

Gravel benches.

Similar small gravel benches occur along the North Fork and Middle Fork of the American at levels rarely exceeding 50 feet above the river. They are found all along the North Fork in this quadrangle and also along the lower course of the Middle Fork. The upper course of the Middle Fork contains relatively few bodies of Pleistocene gravel, as the canyon here is narrow and precipitous.

Basalt.—Scattered eruptions of basaltic lavas took place in different parts of the quadrangle during the early part of the Pleistocene period, that is, during the epoch of erosion preceding the glaciation. The aggregate area covered by basalt reaches scarcely 2 square miles. The basalt rests either on andesite or on rocks of the Bed-rock series. Its relation to the underlying rocks proves that it was erupted after considerable erosion of the andesitic masses had taken place but before the canyons had attained their present depth. Within the limit of glaciation the basalt is covered by glacial drift and moraines, thus showing its pre-Glacial age. The rock is of normal character, black, fine grained, sometimes vesicular, and generally contains small crystals of olivine. These eruptions were evidently local. No continuous flows from the summit of the range westward have been observed.

Near Forest small areas of basalt cap the andesite, reaching over into the Downieville quadrangle. The largest area is the so-called Table Mountain, north of Forest, where the basalt attains a thickness of 200 feet. In the tunnel of the Bald Mountain Extension Company, 600 feet below the summit of Bald Mountain, a dike of this basalt 30 feet wide was found cutting the serpentine and extending upward into the overlying Neocene masses. The basalt in this dike is a black, fine-grained, normal rock, with partly glassy groundmass.

A comparatively large area of basalt and basaltic tuffs is found to the south of American Hill. It is probable that this flow once connected with the small masses of the same rock found as flat-topped hills near Weaver Lake, but the connecting areas have since been eroded. Small areas of basalt were noted at Lindsey Lake and also in the andesite at the Sugar Loaf, half a mile southwest of Shands. Small outcrops of dikes were noted 2 miles east-northeast of Lowell Hill, and on the summit of the ridge south of Burnetts Canyon.

Moraines and other glacial detritus.—The glaciers which covered a large part of the summit region of the Sierra Nevada during the latter part of the Pleistocene period, and which have only recently disappeared, have left abundant traces of their existence in the eastern third of the quadrangle. The glaciated region falls chiefly to the east of a line drawn from Pinoli Peak on the north to the southeast corner of the quadrangle. The marks which the moving masses of ice have left are of a twofold character. In the first place, large areas of the upper region were swept bare of soil. This large glaciated region is strongly characterized by the bare, rounded outcrops of light-gray granitic rocks or reddish-brown slates. The region thus denuded lies east of a line drawn from Granite Canyon on the American River to Cisco, thence follows the railroad to Emigrant Gap, thence extends north-northeasterly up Grouse Ridge, Bowman Mountain, and Pinoli Peak. West of this denuded area is a belt along which all the principal moraines are found, and within which nearly all the débris swept down from above has found a resting place. In some places the moraines are of great depth—sometimes as great as 200 feet—but frequently they spread out, gradually changing to a thin covering through which outcrops of the underlying rocks may be seen. The difficulties in the way of geologic mapping are very evident. No contact lines have been drawn around the morainal areas on account of their imperfectly determinable outlines. Only the heavier glacial detritus which completely covers the ground has been marked as moraines.

Extent of glaciation.

During the Glacial epoch the whole northeastern corner was covered by a continuous sheet of ice, above which only few peaks projected as isolated hills. Among these may be mentioned Pinoli Peak, Findley Peak, English Mountain, Black Mountains, and Signal Peak. On the latter, for instance, glacial detritus is found to a height of 7300 feet. In this case the limit is conspicuous, because the drift consists of white granite bowlders which strongly contrast against the red slate. From this ice sheet tongues projected down the principal streams, separated and fringed by the morainal detritus. While it is probable that the glaciers receded and advanced several times, it can not be said that decisive evidence has been found in favor of two or more definite divisions of the period.

Altitudinal limit of glaciation.

The glacier of the Middle Fork of the Yuba headed north of Meadow Lake in the Truckee quadrangle, and the deep ice sheet followed the course of that stream east of English Mountain and Findley Peak at least as far down as Milton and probably farther.

Middle Fork of Yuba glacier.

The important Canyon Creek glacier headed among the bare amphitheaters around Faucherie and French lakes. The high peaks north and south of Bowman Lake must have projected above its surface. At the sudden bend westward which the glacier took near Bowman Lake a very large morainal mass became lodged in Jackson Creek. Around Bowman Lake the rock is generally swept clean. Through a low gap a branch of the glacier overflowed in a northwesterly direction into the South Fork and a small tongue very probably reached the Middle Fork of the Yuba. The lower limit of the Canyon Creek glacier is not established beyond doubt. A morainal fringe extends along the western slope as far down as east of Graniteville, and scattered glacial débris is found in places above Graniteville. The morainal masses are continuous along the summit of the ridge dividing Canyon Creek and Fall Creek from Texas Creek, but much of this material has doubtless been accumulated by the glacier tongues projecting along the two last-named creeks. It is barely possible that the Canyon Creek glacier may have reached the South Fork of the Yuba, but no well-defined traces of this were found. In the steep canyons the loose morainal débris would be rapidly carried away, thus obliterating the glacial traces.

Canyon Creek glacier.

The heaviest moraines found in this quadrangle extend from Fuller Lake to Bowman Mountain. Fall Creek, with its beautiful glacial cirques near the head, certainly contained an important glacier, which may have reached down as far as the South Fork of the Yuba, but this would have been utterly inadequate to accumulate such large morainal masses, which must, therefore, be considered as largely having been carried down from higher ridges by the main ice sheet. Ice tongues extended far down from the vast ice sheets covering the upper watershed of Fordyce Creek and the South Fork of the Yuba. The main ice stream did not follow the present course of the Yuba below Emigrant Gap. It has been stated before that the deep gap separating the Yuba from the Bear River at Bear Valley represented the valley of the Neocene river formerly filled with lava and gravel and again worn out during the early part of the Pleistocene period. Through this gap the main ice stream must have flowed, continuing on below Bear Valley, as evidenced by the heavy moraines on both sides, which gradually thin out 4 or 5 miles below that point. It is probable, however, that a branch of the South Fork of the Yuba glacier followed the main river for a certain distance. Just how far is not easy to say. Well-defined moraines cover the ridge between Diamond Creek and the Yuba. A little angular material, possibly of morainal origin, is found near the mouth of Canyon Creek. Farther down, at the mouth of Scotchman Creek, a small amount of drift of undoubted glacial origin occurs near the dam built in the creek for the purpose of impounding tailings. This is about 150 feet above the river. Opposite Washington the Pleistocene river valley is covered by angular material, possibly morainal. In conclusion, it may be said that some evidence supports the belief that a narrow tongue of ice found its way as far down as Washington, possibly reinforced by tributary glaciers from Fall Creek and Canyon Creek. There is, however, absolutely no glacial drift on the southern slope from Washington to Omega, nor is there any drift whatever on the lava ridge between Omega and a point a few miles west of Bear Valley House.

Main ice sheet.

Heavy moraines, second in size only to those of Fall Creek, cover a large area south of Emigrant Gap. It is evident that glaciers projecting from the main ice sheet along Lake Valley and Monumental Creek deposited these moraines. Just how far these glaciers reached down the streams can not be decided with certainty. No indications of glaciation were found in the canyon below Red Rock mine.

Moraines near Emigrant Gap.

The glacial accumulations in Big Valley and Granite Canyon are considerable and are evidently due to ice tongues projecting southward from the main ice-covered area.

It is doubtful also how far the glacier extended down the North Fork of the American River. Some angular gravel is found near the mouth of New York Canyon and Sailor Canyon, but it is believed that the main glacier did not extend quite so far west as these points, though there is no doubt that both these ravines at one time contained smaller glaciers near their heads.

North Fork of American River glacier.

On Forest Hill divide no evidence whatever of glaciation is noted except at Westville, at an elevation of 5200 feet. From here up to Secret Canyon the ridge is covered by thin, angular detritus consisting chiefly of quartzite and chert, and gradually growing thicker until at Secret Canyon accumulations begin which can probably be mapped as moraines. This detritus reaches down for several hundred feet on the northern and southern slopes. Small moraines are found on both sides of Tadpole Canyon, indicating that its upper course was occupied by a small glacier. At Canada Hill heavy moraines cover the ridges, while the canyons leading up to Duncan Peak are clearly glaciated. More or less morainal material is found for several miles in all directions from Duncan Peak. Scattered subangular wash similar to that from above Westville covers places in the andesite area 4 miles southwest of Duncan Peak. Glacial detritus occurs on the ridges on both sides of Long Canyon and the Middle Fork of American River. It is not easy to say definitely how far down the Middle Fork of American River the glacier reached, but it is probable that it extended many miles from the eastern boundary of this quadrangle. The glacier of Long Canyon is believed to have extended nearly to the southern boundary of the quadrangle.

Glaciation on Forest Hill divide.

No glacial detritus is found east of the occurrences here described, although the andesite areas offer excellent opportunities to detect it, as morainal matter of slate or granite would be easily discerned on their surfaces.

During the Glacial epoch gravel bars were formed along the rivers below the limit of glaciation. Just where the line should be drawn between pre-Glacial and Glacial gravels of this kind is not quite clear; but it is believed that the benches of the latter kind are rarely more than 25 feet higher than present high-water mark. These bars and benches are found at intervals along all of the principal rivers, and are more extensive than the pre-Glacial Pleistocene deposits, though most of them are so small that they can not be indicated on the map of the scale adopted for this folio.

Post-Glacial gravels.—The most recent Pleistocene deposits comprise the gravel bars at or just above the present high-water mark. Such bars are found along all the principal rivers, chiefly at points where sudden bends occur.

The latest deposits of the rivers include vast amounts of débris of gravelly character which have been dumped into them from the hydraulic mines. In some places the rivers are filled to a depth of 20 or 30 feet with these masses of tailings, which locally form flood plains that are in some places as much as 500 feet wide. Since the cessation of hydraulic mining, about 1888, the rivers have begun to cut down into and remove the débris, and within this quadrangle will doubtless clear their beds completely if no further débris is carried to them from the mines. These bodies of gravel are generally too narrow to be represented on the map. The Middle Fork of the Yuba contains a relatively small amount of tailings, which, moreover, is being rapidly carried away. The South Fork contains masses of tailings in places as far up as Washington. They are usually not more than 10 to 20 feet in depth, and are separated by stretches of abrupt and narrow canyons. Above Washington the bed of the river is comparatively free from débris. Bear River, from a point 3 miles above Dutch Flat, has received a very large amount of tailings. From this point westward its bed is completely filled by gravels, sometimes to a depth of 30 or 40 feet and to a width of from 300 to 400 feet. The lower part of Steep Hollow is similarly overloaded and the Greenhorn River from Quaker Hill down is completely choked by deep tailings.

In the North Fork of the American River the tailings form a continuous mass up to 30 feet in depth and 400 feet in width from the crossing of the Colfax–Forest Hill road down to Auburn. Above this point to the mouth of Canyon Creek there are in places heavy masses of tailings, but they are separated by stretches of narrow canyons in which the river flows over bed rock. Above Giant Gap there are practically no tailings. A considerable amount lies in the lower course of Shirttail Canyon.

The Middle Fork of the American River contains smaller masses of tailings up to a point south of Michigan Bluff.

ECONOMIC GEOLOGY.

COPPER.

No copper deposits of economic value have thus far been developed in this quadrangle. Near the confluence of Bear and Greenhorn rivers, on the road from Colfax to You Bet, a prospect was noted showing disseminated chalcopyrite near the contact of serpentine and slate, but no considerable quantities of the copper minerals seemed to be present.

On Humbug Creek, about half a mile above North Bloomfield, there occurs in the schistose amphibolite a mass of iron pyrite carrying some copper. Its economic value is not known, as the developments are very slight. Disseminated copper pyrite is said to occur at several places in the same belt of amphibolite south of North Bloomfield.

In Rattlesnake Creek, about south of Signal Peak, copper pyrite occurs accompanied by cobaltite, chiefly as impregnations in a gneissoid schist. Two or three shafts have been sunk at this point but have not resulted in developing any considerable amount of ore.

GOLD.

GOLD-QUARTZ VEINS.

The gold-quartz veins are fissures in the Bed-rock series filled with quartz containing native gold and the auriferous sulphides. The quartz has been deposited by waters which circulated in the fissure. The fissures may be large or small, straight or irregular, though the large ones usually approach a plane in configuration. Sometimes a larger vein may split up into a series of stringers. The strike and dip vary greatly in different veins, though in one and the same mining district there is usually a series of parallel fissures. The individual veins are rarely very long. It is unusual to find a vein that can be traced continuously for more than 2 or 3 miles. The gold is seldom equally distributed through the quartz, but is concentrated in more or less regular bodies or ore shoots. These are usually of elongated form and steep dip. Each vein may contain several shoots, so that if one ore body is exhausted thorough exploration of the vein frequently discloses another.

General relations.

Quartz veins occur in practically every one of the formations of the Bed-rock series, and are found in nearly every part of the quadrangle. However, there are three belts in which the majority of them appear to be concentrated. The first extends along the western boundary, the veins occurring in slates, sandstones, diabase, diorite, and granodiorite. The second extends through the center of the quadrangle from north to south, and comprises the vein systems of Alleghany, Minnesota, Graniteville, Washington, and those in the vicinity of Humbug Bar, on the North Fork of the American River. These vein systems are of great importance, as it appears that they have been the principal sources of the gold contained in the beds of the Neocene and present rivers. These veins occur in granite, slate, serpentine, and amphibolite. The eastern third of the quadrangle is relatively poor in gold deposits, and both the present and the Neocene gravels have been less remunerative in this part than in the rest of the quadrangle. Some of the streams in this region are indeed practically barren. However, scattered veins occur in the southeastern part and a vein system of some importance, though not very rich, is found in the vicinity of Meadow Lake and Old Man Mountain.

Occurrence of quartz veins.

The productive quartz veins are younger than the youngest member of the Bed-rock series, that is the granitic rocks, and on the other hand the quartz veins antedate the Neocene auriferous gravels. In all probability the time of their formation falls in the early Cretaceous. But it is certain that the Carboniferous series contains some quartz veins formed before the deposition of the Mariposa slates and the great igneous intrusions, though it is not probable that these quartz veins are very numerous or very rich. That quartz veins occur is proved by the plentiful occurrence of quartz pebbles in the conglomerates of the Mariposa slates. These conglomerates have been found to carry a slight amount of gold, which apparently has been derived from older quartz veins. Another evidence in favor of the existence of an older series of quartz veins is that contorted veins are occasionally found in the Carboniferous slates, which bear evidence of having participated in the compression of the sedimentary series.

Age of quartz veins.

Detailed descriptions.—The great Mother Lode of California can not be traced continuously any farther than the Middle Fork of the American River, in the adjoining Placerville quadrangle. It splits here into several forks and a peculiar kind of deposit appears, usually referred to as seam diggings. These consist of a great number of small seams belonging to one or more fissure systems and all containing gold, some being very rich The usual way of mining the decomposed, softened upper part of these deposits is to hydraulic them, as would be done with the placer gravels. Where the seams occur in hard, fresh rock the mass, as a whole, is rarely rich enough to exploit. At the southern boundary of the quadrangle, 3 miles south-southeast of Weimar, is a deposit of this kind which has been somewhat extensively worked. It lies on the contact of Carboniferous slates and a small serpentine mass; it is known as the Vores mine.

Character of the Mother Lode.

The Black Oak mine is situated 2 miles south-southeast of Weimar in the Mariposa slates. The vein is traceable for a distance of 2500 feet and is developed by several tunnels. It is a well-defined fissure vein 2½ to 3 feet wide, carrying rather coarse gold and some copper and iron pyrite. The ore is stated to average $15 to the ton, and considerable work has been done on this mine since 1894. A mile and a half west-northwest of Colfax are the Rising Sun and Live Oak quartz mines. The Rising Sun is stated to have produced $2,000,000. The average value of the quartz is said to be $28 per ton. The vein is a well-defined fissure from 2 to 3 feet wide, and the quartz contains a small amount of iron and copper pyrite. The gold is coarse, frequently visible to the naked eye. The Rising Sun is developed by means of a shaft 749 feet in depth. After a long period of inactivity the mine has recently been reopened and a tunnel 2000 feet long is being driven from near Bear River which will tap the vein 500 feet below the surface. The adjoining Big Oak vein has also been worked to considerable extent. From 1883, when it was re-located, to 1887, it is stated to have paid a profit of $30,000. Between Colfax and Nevada City intervenes a stretch of comparatively barren ground. The Jack Rabbit vein, northwest of Buena Vista, has been explored to a depth of 270 feet, but work has been suspended for several years.

Black Oak, Rising Sun, Live Oak, Big Oak, and Jack Rabbit mines.

Near the boundary of the quadrangle, a short distance east of Nevada City, appears an extensive vein system, described in detail in Folio No. 29. The veins, which are very numerous, have chiefly an east-west direction and a moderately northerly or southerly dip. They occur in granodiorite and sedimentary rocks, the more important being the Federal Loan, the Mayflower, and the North Banner.

Federal Loan, Mayflower, and North Banner mines.

Kirkham and Morgan.

The region southeast and north of Nevada City is remarkably poor in paying quartz veins. About a mile and a half northwest of Blue Tent two locations have been made, called the Kirkham and the Morgan, upon which some work has recently been done.

Delhi, Gothardt, and Live Oak.

North of this there is nothing of importance until Grizzly Ridge is reached. On the northerly slope of this crops the famous Delhi vein. It is contained in the black, hard siliceous rock of the Delhi formation. This mine has produced a large amount of gold and its vein is characterized by having an extensive and rich shoot of coarse gold. The vein is opened by tunnels. The mine has been idle since 1893, as the shaft sunk below the tunnel level was found to carry an amount of water which could be handled only with great expense. It was again opened in 1898. There are several other veins in the vicinity of the Delhi, the most important of which is the Gothardt, cropping partly in slate and partly in diorite. The mine is developed by a perpendicular shaft 380 feet in depth. The Live Oak mine is located three-fourths of a mile west of the Delhi, and has been developed by several tunnels.

Alaska vein.

Half a mile north of Pike, in Sierra County, crops the Alaska vein, which was worked to a considerable extent about 20 years ago, and which is stated to have produced much rich ore with coarse gold.

Veins in serpentine.

The main mass of the Delhi slates is very poor in quartz veins. Neither do any workable veins occur, as far as known, in the adjoining Cape Horn slates. The narrow serpentine belt separating these two formations in the northern part of the quadrangle contains one large vein, which is characterized by a considerable mass of dolomite and mariposite as is usual with veins in serpentine. The vein has been worked to some extent, and a large mill was once erected near Kanaka Creek. The ore is stated to be low grade.

The great serpentine belt traversing the quadrangle from north to south contains a number of gold-quartz veins, many of which are very rich. Many small quartz veins occur along its contacts, but they are generally noted for a pockety character, containing small chimneys of rich ore. Dolomitic rocks, the result of alteration of serpentine by mineralizing solutions, are frequently found at the contact of the serpentine and slate.

Veins on Forest Hill divide.

A large body of low-grade ore occurs between amphibolite and serpentine on the south side of the Middle Fork of the American, about 1½ miles southeast of Forest Hill. This ore body apparently chiefly consists of amphibolite altered by mineralizing solutions. A short distance south from the mouth of Volcano Canyon the serpentine contains a small vein which has been worked on a small scale. In the hanging wall of this vein lies a narrow dike of diorite with brown hornblende. A short distance east of Forest Hill, on the contact of clay slate and amphibolite, is a wide belt of altered rock containing a quartz vein from which some rich ore was extracted a long time ago. This is known as the Moss Ledge. All along the serpentine contact up to Michigan Bluff there are evidences of the existence of many small veins containing coarse gold, which have been worked in a desultory way. The amphibolite area north of Baker Divide contains several quartz veins with a northwesterly strike and steep northeasterly dip. Most prominent among these is the Drummond mine.

Red Point, Buch and Abrams, Gold Canyon, Plumbago, Rainbow, Appel, Fesslers, and Oriental veins.

For a long distance north of this place the serpentine belt contains no quartz veins. Half a mile north of Washington is Red Point mine; it consists of a large body of low-grade ore chiefly composed of altered serpentine containing many small quartz veins. Attempts have been made to mine this at various times, but they have not proved very successful. The amphibolite and serpentine north and south of the canyon of the Middle Fork of the Yuba contain an important system of veins similar in strike, dip, and general character. The direction of these is generally west-northwest to east-southeast. The dip is from 35° to 45° N. They are well-defined quartz veins containing coarse gold and a small amount of sulphides. Most of them appear to be pocket mines, that is containing small chimneys of exceedingly rich ore. Near Orleans the Buch and Abrams vein is worked to some extent. From Minnesota eastward extends the Gold Canyon vein, which for 1½ miles cuts across the strike of the amphibolites but disappears a short distance after entering the serpentine. The mine is situated close to the river and has been worked at intervals. Is said to have yielded $700,000. Half a mile east of Minnesota is the Plumbago mine, celebrated for its rich ore with coarse gold. After many years of quiescence this mine has recently been opened. Near Chips Flat extends the Rainbow vein, similar in character and production to the Plumbago. In the canyon of Kanaka Creek, upstream from the bridge between Chips Flat and Alleghany, are a number of small veins from which at intervals very rich quartz has been extracted. This rich quartz with coarse gold is usually simply crushed in a hand mortar and washed in pans. Just above the bridge is the Appel vein, reported to have yielded about $40,000 from 1886 to 1891. Half a mile farther up the creek is Fesslers mine, from which $50,000 were said to be extracted in the manner above described during 1890–91. One mile west of Alleghany is the Oriental mine, reported to have yielded $3,000,000 in early days, one pocket containing $740,000. After eighteen years of quiescence this mine has recently been reopened.

On the contact between serpentine and slate one mile south of Mountain House, Sierra County, lies the Bush Creek vein, reported to have been worked with good results about fifteen years ago.

Veins between American Hill and Michigan Bluff.

From American Hill to Michigan Bluff extends a belt along which quartz veins rich in gold appear to be especially abundant. These veins generally occur in clay slate, though one branch of the belt is contained in the granite area of Canyon Creek. The veins are well-defined quartz veins of ordinary type, often rich in coarse gold, and usually containing a few per cent of sulphides, chiefly iron pyrite, with small amounts of galena, zinc blende, and chalcopyrite. The individual veins may in some cases be traced for a distance of more than a mile. Along this belt, as well as some distance west of it, the gravel deposits are especially rich and contain coarse gold.

American Bar and Herman veins.

Southwest of Michigan Bluff, on the north side of the American River, is the American Bar vein, inclosed between a hanging wall of slate and a foot wall of altered porphyry. This vein, which is from 3 to 5 feet in width, was worked in 1895 and 1896, but is now said to be idle. At Byrds Valley, near Michigan Bluff, the placer mines contain exceedingly coarse and often crystallized gold plainly derived from quartz veins in close proximity. Several quartz prospects were noted a mile northeast of Michigan Bluff, but little work has been done on any of them. Near Byrds tunnel the slate contains large quartz veins, which, however, appear to be barren. The Herman vein, 5 miles north of Deadwood, is inclosed in a quartzitic sandstone, dipping 25° to the southeast. This vein has been worked continuously and successfully since 1894. The vein is from 3 to 12 feet wide, the quartz containing a large quantity of sulphides in addition to free gold.

Lynn and Pioneer and Dorer veins.

In the vicinity of Humbug Bar the quartz veins are strongly developed. Most prominent among these is the Lynn and Pioneer, which has been worked persistently and successfully during the last few years. The veins are well-defined normal quartz veins containing free gold with a small proportion of sulphides. During the last few years this mine has produced about 8000 to 10,000 tons of ore per year, averaging from $10 to $16 per ton. The mine is opened by three crosscut tunnels, the lower tunnel being 1400 feet long. The vein has been followed 2500 feet along this level. The Dorer mine crops on the steep hillside north of Humbug Bar, and is inclosed in clay slates and quartzitic sandstone. This vein, similar in character to the Lynn and Pioneer, has been worked at intervals during the last 15 years. It is not improbable that thorough prospecting will develop valuable quartz mines in the rugged canyons to the east of Shady Run. Several prospects are located there, among which may be mentioned the Avery, Golden West, and Fairmount. The slates in that vicinity are known to contain a large amount of quartz.

Red Rock, Washington, Erie, National, and Culbertson veins.

The Red Rock mine is situated 2 miles southeast of Blue Canyon. It consists of a long streak of slates penetrated in all directions by veinlets of quartz, and it also contains a mass of solid white quartz. It is followed on the west side by a narrow streak of schistose amphibolite also containing small quartz stringers. The whole forms a large mass of low-grade ore. On Texas Hill, 3 miles farther east, several large veins crop. None of these have been worked to any considerable extent. Several prospects have been worked near Italian Bar in the canyon of the North Fork of the American. Some prospecting work has also been done on the veins in Bear River Canyon, 4 miles west-southwest of Emigrant Gap. To the northwest of Emigrant Gap extends an important series of quartz veins crossing the South Fork of the Yuba, often known as the Washington quartz belt. Many of the principal mines are situated in the canyon of the South Fork of Yuba River. The Washington mine, near the mouth of Canyon Creek, cuts across the strike of the slates and is nearly perpendicular. Some 10 years ago this vein was worked, producing a considerable amount. It is developed by means of a tunnel on the river level and a shaft having a depth of 600 feet below this level. To the north of the Washington mine, in Poorman Creek, is the Erie vein, which has been worked at intervals. North of this again, 2 miles west of Graniteville, are located the National and Culbertson veins, also in clay slates, dipping 75° E. The quartz is from 1 to 4 feet wide, and contains less than 1 per cent of sulphides. The Culbertson and National mines have been worked continuously for the last few years, and are developed by shafts to a depth of 180 feet.

Spanish mine.

The Spanish mine is situated 3 miles north-northeast of Washington. The Spanish vein consists of a body of clay slate 20 to 30 feet wide, filled with quartz stringers and adjoined on the west by a narrow dike of schistose amphibolite, probably an altered diorite. This mass forms a large body of low-grade ore, which, however, has been worked with profit under exceptionally favorable conditions. The ore is said to average from $1 to $2 per ton. The Spanish vein is traceable for a distance at least of one mile and possibly still farther south.

Yuba and Eagle Bird veins.

The granite area of Canyon Creek contains a number of important veins extending between Graniteville and the South Fork of the Yuba. The Yuba mine, in the canyon of the South Fork of the Yuba, was worked extensively some 10 years ago but is now idle. The mine is developed by means of a tunnel from the river level to a shaft which extends 800 feet below this level. Following the Yuba vein for some distance and embedded in the granite, is a narrow streak of slate and limestone. The ore consists of clean, pure quartz with free, coarse gold, galena, pyrite, and pyrrhotite. The Yuba vein is from 2 to 16 feet wide. Half a mile above the Yuba mine is the Eagle Bird, well known as an important producer. The vein, traceable for a distance of a mile south of the river, is similar to the Yuba in width and character of ore. It is developed by means of tunnels and a shaft 800 feet in depth. Following the vein there is in many places a greenish porphyry, as well as similar masses of quartzite.

North of the Yuba and the Eagle Bird extends a series of veins, on all of which some work has been done, but none of which have proved very productive. This belt extends continuously nearly as far north as Graniteville, the most northerly location being the Wisconsin.

Rocky Glen and California veins.

Near the contact of granite and slate one mile south of Graniteville is the Rocky Glen mine, worked successfully for many years. Three miles south of Graniteville, also near the contact of granite and slate, is the California vein, worked at intervals with good success and lately developed by a tunnel 2000 feet long.

Veins near Canada Hill, Sailor Canyon, and Duncan Peak.

The southeastern part of the quadrangle is in general poor in workable quartz veins. Several prospects have been developed near Canada Hill. At Sterrett, in Sailor Canyon, a prominent quartz vein appears in the Juratrias slates. This vein, now known as La Trinidad, carries a considerable amount of arsenopyrite, and apparently contains a less amount of free gold than is ordinarily found in this region. A small quartz vein crops near Flat Ravine southwest of Duncan Peak and a little development work has been done on it. The quartzites in the vicinity of Duncan Peak contain a great number of irregular stringers and veinlets, many of which are very rich in coarse gold and have furnished material for the gravels successfully worked in that vicinity. Very few large and continuous veins have, however, been found. On the broad divide between Deep Canyon and the Middle Fork of the American several quartz veins have been located in quartzite and slate. All of them appear, however, to carry a low-grade ore.

Veins near Canyon Creek and Grouse Ridge.

The eastern part of the Canyon Creek granite area appears to be entirely barren of quartz veins. Some occur in the wedge-like mass of sedimentary rocks between the two granite areas, but they are neither numerous nor rich. Small stringers of gold quartz have been found on Grouse Ridge; from these are probably derived the gold in the placers of Fall Creek. Near the contact of granite and slate south of Bowman Lake the formation contains a belt of decomposed rock impregnated with iron pyrite which is said to carry some gold. It is known as the Jefferson mine. A short distance northeast of Shotgun Lake some prospects are sunk on altered rock containing pyrite.

A little south of Signal Peak a few small quartz veins have been prospected, apparently, however, with no great success.

Fissure veins between Summit City and Old Man Mountain.

Between Summit City and Old Man Mountain crops a series of veins very different in their character from the typical gold-quartz veins of California. They are fissure veins, often without well-defined walls. The ores consist of iron pyrite, arsenopyrite, and zinc blende, carrying a moderate amount of gold. Free gold occurs only in the decomposed surface material. The gangue consists of black tourmaline and epidote. Frequent attempts have been made to exploit these veins, but they have not generally been successful, owing to the low grade, the absence of free gold, the climatic conditions, and the difficulty of communication. The veins are contained in granodiorite, diorite, and diabase-porphyrite.

North of English Mountain, at Jackson Lake, in diabase-porphyrite, crops a vein which is similar in its ore and character to the veins of Summit City. The decomposed portions contain a considerable amount of free gold, and the vein was successfully exploited during 1895 and 1896.

AURIFEROUS GRAVELS.

Oregon Creek and vicinity.

Neocene pre-volcanic gravels.—Along Oregon Creek several bodies of gravel are exposed, lying on flat benches sometimes less than 100 feet above the stream. The gravels at Tippecanoe are 100 feet thick and consist of quartz and chert pebbles, often imperfectly washed. They contain no volcanic rocks. The course of the Neocene stream must, as shown by bed-rock relations, have followed the present Oregon Creek. The gravel at Remargis and Gales diggings, 2 miles farther up the creek, is similar. At Tippecanoe a few acres have been hydraulicked, and some work has also been done at Gales; the gravel is here 50 feet thick and is covered with 10 feet of pipe clay. Small bodies of gravel crop near Nelson mill, and below the andesite one mile east of Plum Valley. A sharply defined channel containing little if any gravel is noted at Daneckes tunnel, 2½ miles northwest of Tippecanoe. This Neocene gulch probably drained northward.

North Columbia.

A junction of two important streams took place near North Columbia, and here the Auriferous gravels are developed to a greater extent than at any other place. In the Smartsville quadrangle there is a large area of gravel extending from Badger Hill to the limit of the quadrangle. This is continued in this quadrangle as far east as North Bloomfield, covering about 8 square miles. There was doubtless a deep channel with slight grade running from Grizzly Hill (one mile southwest of Kennebec House) to Badger Hill, where it was joined by the steeper channel of North Bloomfield from the east. The North Columbia gravels are among the most extensive and deepest known, the depth along the center of the channel being from 400 to 500 feet. The gravel in the deepest trough, exposed at Badger Hill and Grizzly Hill, is coarse and made up largely of metamorphic rocks, while the top gravel, spread out over the benches, is fine and much more quartzose. Near the surface, and especially up toward the base of the lava flow, there are heavy masses of sand and light-colored clays.

The gravels at North Columbia are owned chiefly by the Eureka Lake Company, their claims covering an area of 1445 acres along 2½ miles of channel. A large amount of surface work has been done and 150 feet of gravel has been washed off. The deep part of the deposit exposed at Grizzly Hill can be reached only by running long and expensive bed-rock tunnels; this would have been done but for the injunctions against hydraulic mining. It is estimated that 25,000,000 cubic yards have been washed off and that 165,000,000 cubic yards remain.

North Bloomfield.

At North Bloomfield the exposures are excellent in the hydraulic bank along the center of the channel. The bed rock rises north and south of the main channel. Across the bottom it is nearly level for 300 or 400 feet. The deepest blue gravel is 130 feet thick; this is capped by heavy bodies of light-colored clay and sand interstratified with fine gravel and near the top occasionally also with andesitic tuff; the clay and sand may reach 150 feet in thickness. This is again covered by 600 feet of tuffaceous breccia. The lower surface of the breccia is uneven, as shown by the fact that sand and clay crop a short distance east of the Derbec mine. About one mile north of North Bloomfield the channel forks again below the lava. The main fork has its inlet from the lava ridge north of Backbone House, where the configuration shows the existence of a deep channel, along the center of which Bloody Run has excavated its canyon. Gravels capped by heavy masses of sliding clay are here exposed.

Hydraulic mining has been carried on at North Bloomfield on a very large scale. The excavations extend for 5000 feet, and are 500 to 600 feet in width. The banks are as much as 500 feet in height. The deposit has been opened by a bed-rock tunnel 7874 feet long, starting from Humbug Canyon. The sum of $3,000,000 is said to have been expended upon this tunnel, the water supply, and other preliminary work. Shortly after the completion of the tunnel hydraulic mining was suspended by injunction of the courts, and since then the only gravels worked have been those the tailings of which could be impounded before reaching the river.

The average yield per cubic yard is from 4 to 10 cents. Most of the value is contained in the deep gravels (130 feet), and in these the richest parts are the first few feet from the bed rock. Some portions of the clay and sand near the top are almost barren. Owing to the great width of the channel the gravel next to the bed rock is rarely rich enough for drifting. The yield since 1866 is approximately $3,500,000. About 30,000,000 cubic yards have been excavated and 130,000,000 are said to remain. The same amount may be available in the vicinity of Lake City.

Mining operations from the Derbec shaft have proved the existence of a deep channel extending for several thousand feet eastward. This is not the main North Bloomfield channel, though it connects with that a short distance westward. The Derbec channel, which has a steep grade, has been mined upstream from the shaft for a distance of 7000 feet, following the curves; the width of pay gravel was from 150 to 600 feet, the height was from 8 to 16 feet from the bed rock. The gravel is coarse with many bowlders, some of which are of granite. The average value per ton is $2.47. The mine was in operation from 1877 to 1893, and the production in some years reached $200,000.

Relief.

There can be but little doubt that the Derbec channel continues toward Relief. At Relief, erosion has exposed a deep trough in the old bed rock and about 200 acres of auriferous gravels. The oldest gravels, as usual coarser and containing less quartz, are 60 feet deep and are covered by from 100 to 200 feet of alternating sand, fine quartz gravel, and clay. Some hydraulic work was done long ago at the southern and eastern rim. For many years drifting operations only have been carried on. The Union tunnel, about 2500 feet long, has been driven from the southwestern side of the gravel area and amounts up to $30,000 and $40,000 per year have been produced for a number of years. Drifting has also been done from the Blue Gravel tunnel, started from the northeastern side of the deposit.

Mount Zion.

For a long distance east of Relief the bed rock keeps high and no gravel outcrops along the contact. But at Mount Zion, at Devils Canyon, fine quartz gravel having a thickness as great as 50 feet crops below the North Bloomfield ditch for a distance of nearly one mile. Some little hydraulic work as well as drifting has been done here. Many years ago the main tunnel running due west for 1400 feet struck bed rock pitching west. It is probable that this gravel filled a tributary running northward and joining the Derbec channel.

Cherry Hill and Shands.

At Cherry Hill, between Shands and Mount Zion, a small body of gravel crops below the North Bloomfield ditch. A few very small areas were noted at Shands; the largest was 100 feet thick, composed of well-washed pebbles and covered by subangular gravel. The small patches north and south of Graniteville are also partly subangular gravel. Well-washed gravel crops below the andesite north of the town but is thin and irregular. A small rapidly rising channel probably continues for some distance below the lava.

Snow Point, Orleans, and Moores Flat.

At Snow Point and Orleans are small bodies of auriferous gravel, the bed rock rising rapidly southward. At both places the gravels have been nearly exhausted by hydraulic mining. A little drifting has also been done at Snow Point. At this place the bank is 135 feet high; the lower 15 feet contains coarse gravel covered by 90 feet of fine, sandy quartzose gravel, again overlain by 20 feet of clay. At Orleans the gravel was also largely quartzose. West of Orleans is Moores Flat, where a considerable body of gravel is exposed. It is of the same character as at Snow Point, from 100 to 130 feet thick, and is covered by andesitic breccia. Bowlders of quartz from 2 to 6 feet in diameter are found on the bed rock. It is estimated that 26,000,000 cubic yards have been washed off and that perhaps 15,000,000 remain.

Woolsey Flat.

At Woolsey Flat there is likewise a large body of gravel exposed. The heavy gravel up to a thickness of 100 feet is similar in character to that just described, but it is then covered by as much as 150 feet of clay. In all these gravel bodies the gold on the bed rock is rather coarse. But little hydraulic gravel remains at Woolsey Flat, as the thickness of the nonproductive strata is rapidly increasing. The production of these hydraulic mines, while very large, is not definitely known. None of them have been in operation since 1886.

Minnesota and Chips Flat.

The most probable course of the old channel is, as indicated on the map, approximately parallel to that of the modern river. Somewhere near Orleans the old river was joined by the Forest tributary, continuously traceable by way of Minnesota, Chips Flat, Alleghany, and Forest. At no place along this old tributary are any considerable bodies of gravel exposed. At Minnesota a small amount of hydraulic work has been done and about 20 feet of fine quartz gravel, mixed with larger bowlders of the same material, are exposed. The gravel is coarsest on the bed rock. The channel extending below the lava to Chips Flat is said to have been drifted along its entire length and to have been very rich. At Chips Flat are a few acres of exposed gravel, the banks of which show a few feet of coarse gravel with well-washed quartz bowlders near the bed rock, 30 feet of fine gravel, 30 feet of clay, and above this the volcanic capping. A few smaller patches of gravel are exposed on the same ridge, the largest of which, east of Chips Flat, is called Balsam Flat.

Smiths Flat.

The continuation of the Minnesota channel is found one mile south of Alleghany at Smiths Flat, somewhat higher in elevation than Chips Flat. Here a little hydraulic work has also been done, and the banks are 50 feet in height. From here the channel has been drifted through to Forest. As usual in this channel the bottom gravel is coarse and contains many flat cobbles and bowlders of a bluish-white siliceous slate; also much quartz. The gold on the bed rock is coarse and has often worked its way down some distance into the decomposed bed rock. The production of this channel has amounted to several million dollars though it is impossible to obtain exact statistics. One of the most successfully worked claims (1855–1863 inclusive) was that of the Live Yankee, extending along 2600 feet of channel. Its production was nearly $700,000.

Forest.

A small amount of heavy gravel crops at Forest, but the channel enters the northern ridge immediately and continues in a north-northeast direction. It was worked by the Bald Mountain Company from 1872 to 1879 or 1880 for a distance of about a mile, producing $150,000. The gravel was extracted to a height of 3½ feet, including one foot of bed rock. The yield per cubic yard of unbroken gravel was about $7. A shaft sunk 1800 feet from the mouth shows 215 feet of clay and sand covering 15 feet of gravel; no such heavy masses of silt are found farther down on this channel The Bald Mountain channel was found to be cut off by a lower, intervolcanic channel filled with lava, but continuous beyond this toward the Ruby mine in the Downieville quadrangle

Kanaka Creek.

The North Fork Company has a long tunnel running in a northwesterly direction for more than a mile and some good drifting ground; this tunnel is probably on a tributary to the main channel. The Bald Mountain Extension Company for some years worked a branch of the Bald Mountain channel by means of a tunnel 1½ miles long running northwest under Bald Mountain. They have now transferred operations to a tunnel at the head of Kanaka Creek in Downieville quadrangle. This channel is also cut by a lower intervolcanic channel. At the Ruby mine both an older and more recent channel have been worked. Small drifting operations have been carried on at various points on the ridge west of Alleghany.

Wolf Creek.

Returning now to the main old channel, traced as far as Snow Point, its continuation is without much doubt to be found at American Hill and Bunker Hill on Wolf Creek. At American Hill and for a mile westward around the head of Little Wolf Creek bench gravels crop. At Bunker Hill, on the east side of Wolf Creek, a mass of gravel about 300 feet thick, covered by clay and sand lies in a deep trough in the bed rock. It is believed that this channel extends in a northwesterly direction under the lava. Two long tunnels, now inaccessible, were driven some time ago. They are said to have shown the existence of two channels, at considerably different elevation. The reports do not agree as to whether they would pay for drifting.

Blue Tent.

At Blue Tent the gravel crops extensively below the lava, filling a deep trough in the bed rock, the deepest part having the same elevation as Grizzly Hill, across the canyon. The bottom gravel is coarse and cemented, and is covered by over 300 feet of light-gray sand and clay mixed with fine quartz gravel. The sand is particularly abundant and nearly barren. About 15,000,000 cubic yards have been removed and some 90,000,000 remain, much of which is barren clay and sand. The lower gravel averaged 15 cents or more per cubic yard, while the sandy top gravel contained only 2½ cents.

Northeast of Nevada City.

On the ridge northeast of Nevada City a small but rich channel has been drifted from the East and West Harmony inclines. The gravel, which is partly subangular, is taken out to a depth of 4 feet. In Rock Creek below the andesite lie large masses of clay and sand similar to the deposits of Blue Tent. Still larger accumulations are exposed at Scotts Flat and Quaker Hill. The gravel, covered with rhyolitic tuff and andesite, fills a deep trough well exposed by Deer Creek and Greenhorn River. Along the principal channel the gravels are nearly 600 feet deep; the bench gravels surrounding the deepest trough are about 300 feet in depth. At Hunts Hill the deepest channel is exposed by mining operations at about the level of the tailings in the river. North of this point it is not visible until exposed again at Blue Tent. The evidence of the bed rock relation and the accumulation of gravel clearly show that the deep channel is continuous from Hunts Hill to Blue Tent. A shaft has been sunk in the old dippings at Quaker Hill and bed rock was found at an elevation of about 2650 feet. A shaft sunk in the creek at Scotts Flat struck bed rock at an elevation of about 2770 feet, the lowest bed rock not being found. At Quaker Hill the width of the channel said to pay for drifting is about 130 feet and the depth of pay gravel is from 4 to 16 feet. As usual the gravel is coarse and cemented in the deep trough, while the bench gravels, several hundred feet thick, are chiefly fine quartz gravel mixed with sand.

The yield of the top gravel rarely exceeds 6 cents per cubic yard in fine gold, size of a pinhead or less, while the bottom gravel may be very rich. It is estimated that near Scotts Flat 12,000,000 cubic yards have been removed, while 35,000,000 measures the amount at Quaker Hill, where the gravel banks reach a thickness of 250 feet. A vast amount of workable gravel, estimated at 140,000,000 yards, remains at Quaker Hill. At both Quaker Hill and Scotts Flat it is difficult, if not impossible, to obtain dumping ground and sufficient grade for sluices.

Quaker Hill.

Deep gravels fringe the rhyolite for 3 miles east of Quaker Hill and represent without much doubt a tributary crossing the ridge near Center House (Galbraiths). South of this place there is about 100 feet of clay underlain by some gravel. Here some drifting has been done, both on the north and south side. Heavy clay masses are exposed at Burrington Hill, where some hydraulic work was done long ago. The gravel of this tributary has also been hydraulicked on the north and south side of the Quaker Hill ridge.

High bed rock appears on the ridge 3 miles northeast of Quaker Hill. East of this are exposed the small Red Diamond channel, on the north side of the ridge, and other channels covered with deep clay on the south side. A little work has been done on all of them. At Coopers mill it is said that an old incline was sunk on the rim, tracing the bed rock down to an elevation of 3500 feet. If this is correct it would be highly remarkable, as this is considerably lower than the rim rock at any point in this lava area, and would imply the existence of a closed basin. The important Centennial–San Jose channel is covered by this same lava area.

Buckeye Hill is a small mass of bench gravel southeast of Quaker Hill. The gravel has been almost entirely removed.

You Bet.

At Red Dog and Hawkins Canyon, near You Bet, the deep channel has again been exposed, and is beyond doubt continuous between the two points. The gravel is similar to that of Quaker Hill. The deepest gravel has been hydraulicked only at the places mentioned, but considerable drifting by means of tunnels and inclines has been done from Niece and West's claims for $1\frac{1}{2}$ miles northeast, on the Steep Hollow side. The channel has very little fall, the average elevation being 2620 feet. It is estimated that 47,000,000 cubic yards of gravel have been removed, leaving over 100,000,000 yards available. Much of this would, however, be difficult to wash on account of lack of grade. Reports of yield and grade of gravel are not available, but the You Bet diggings have probable produced $3,000,000.

Little York and Dutch Flat.

The Little York gravel area contained a fragment of the old deep channel which has been almost completely removed by hydraulic mining. The character of the gravel is similar to that at You Bet. As usual, the narrow, deep channel contains a hard cemented gravel, 30 or 40 feet thick, capped by as much as 350 feet of fine gravel interstratified with some clay and sand. Large bowlders of quartzite and quartz occur on the bed rock, both in the deep channel and on the benches. The yield has probably exceeded $1,000,000. The continuation of the deep channel is found at Dutch Flat, and its direction is plainly marked by the small intervening gravel bodies of Missouri Hill and Eastman Hill. The principal area at Dutch Flat extends east to west for a mile; the gravel has a maximum depth of about 300 feet, the lower 150 feet consisting of coarse blue gravel, largely made up of metamorphic rocks, well cemented and covered by a varying thickness of finer quartz gravel, clay, and sand. In the lower gravel and on the bed rock heavy bowlders are plentiful. The channel has a very strong grade, in marked contrast to the level stretch below You Bet. Hydraulic work has been done chiefly at the eastern and western ends, at both of which places the deep bed rock is exposed. About 90,000,000 cubic yards have been washed and a considerably less amount remains. Practically the whole extent of channel has been drifted, and the cemented gravel worked in stamp mills. The yield is not known, but probably exceeds $3,000,000. The Polar Star gravel is said to average 11 cents per cubic yard.

From Dutch Flat the gravel area continues southward, narrowing to a few hundred feet at Squires Canyon, and widening to from 1500 to 3000 feet near Gold Run; its southern end, overlooking the American River, is called Indiana Hill. Over a large part of this area the gravel is deep, reaching in places 300 feet, and even a maximum of 400 feet.

Indiana Hill, Jehosaphat Hill, and Gold Run.

The surface gravel is, as usual, reddish, containing many small quartz pebbles, and some interstratified sand and clay; the bottom gravel in the deep trough at Indiana Hill shows 60 feet of coarse, cemented, blue gravel with a large proportion of metamorphic bowlders; the lowest trough is here from 300 to 500 feet wide. The question whether there is a deep and continuous channel from Indiana Hill to Dutch Flat is one of much importance. Deep bed rock has been found at Jehosaphat Hill, half a mile south of Dutch Flat, having an elevation of 2877 feet, this part of the channel clearly connecting with Thompson Hill, a short distance northward. In Squires Canyon, where the gravel area narrows down to 500 feet in width and the elevation is about 3050 feet, a shaft is stated to have been sunk to a depth of about 150 feet, striking pitching bed rock at that depth and showing the existence here of a deep trough having an elevation of less than 2900 feet. If this is correct there is little doubt that a continuous deep channel exists between Indiana Hill (elevation 2792 feet) and Dutch Flat with a moderate grade of 25 feet per mile toward Indiana Hill. Bed rock has again been exposed 1200 feet farther north by the Cedar Creek tunnel and again 2000 feet from Indiana Hill by a tunnel from Canyon Creek, run by the Gold Run Ditch and Mining Company. From the former place the bed rock is said to slope gently toward Indiana Hill. The so-called '49 shaft was sunk nearly to the bottom of the channel between Gold Run and Indiana Hill, but exact data regarding its elevation were not available. Another shaft, 75 feet deep, was sunk to the bed rock in Canyon Creek about half way between Gold Run and Dutch Flat. Extensive hydraulic mining operations were carried on at Gold Run for about ten years, in which time perhaps $3,000,000 or more were extracted. Some 84,000,000 cubic yards have been washed off but an equal quantity, estimated at 92,000,000, remains. An area of 555 acres has been washed off to an average depth of 75 feet. At Indiana Hill the bottom gravel was drifted and crushed in mills. The yield per cubic yard of hydraulic gravel is said to be 11 cents, but this estimate is in all probability too high. The drifting ground at Indiana Hill yielded between 1872–1874 at the rate of $9 per cubic yard of gravel in place.

Alta.

Above Dutch Flat, toward Alta, is the gravel hill of Nary Red, the narrow channel of which has been drifted and hydraulicked; the gravel is a medium-fine red quartz, covered with rhyolitic clays. From here a channel extends in the hill toward Alta. A shaft sunk at Alta 35 feet below the railroad found bed rock at 132 feet. A tunnel extends from Canyon Creek, one-half mile south of Alta, to the shaft, and the gravel in the channel is now being worked. The gravel is soft quartzose, not cemented. From this point a branch channel probably crosses Canyon Creek and extends to Moody Gap, east of which the remainder is probably eroded. Another branch extends from Alta eastward, probably emerging at Shady Run, and grading sharply westward. It is mostly filled with rhyolitic clays, though a bank of gravel also appears on the northern rim which has been washed. Minor drifting operations have also been undertaken in this vicinity. A remainder of the same channel is preserved at Lost Camp, 2 miles south-southeast of Blue Canyon. Here are about 120 acres of quartzose, imperfectly washed gravel, 50 to 75 feet deep, containing some rather large bowlders. Only a smaller portion has been hydraulicked.

Liberty Hill and Lowell Hill.

A branch of the Dutch Flat channel continued across the present Bear River. Elmore Hill, on the point between Bear River and Little Bear Creek, has been almost completely washed off. Rising at a rapid rate the continuation of the channel is found at Liberty Hill. The gravel is here about 60 feet deep, 30 feet of reddish quartz gravel covering the same amount of blue gravel, full of very large bowlders of gabbro and serpentine. The amount of gravel removed is estimated at 2,000,000 cubic yards, some 16,000,000 remaining. The channel continues up to Lowell Hill, but the gravel is here covered by very heavy masses of light-colored clay. At Lowell Hill the gravel is 30 feet deep, the coarse bottom gravel being covered by finer quartzose gravel. The heavy clay banks make hydraulic working difficult. Considerable work has, however, been done at the Planet mine. Drifting operations have also been undertaken south of Nigger Jack Hill, at the Valentine mine, and farther south opposite the Planet at the Swamp Angel.

Remington Hill.

Opposite Lowell Hill lies Remington Hill, at a slightly higher elevation. Here, again, is an old depression filled with gravel of which a few acres are exposed. The gravel is similar to that of Lowell Hill and is capped by heavy masses of clay. The amount excavated is estimated at 1,750,000 cubic yards, while possibly 600,000 cubic yards remain. Much of this, however, is heavily capped by clay and volcanic tuff. The channel has been struck by two drift tunnels a little eastward, making it possible that the channel comes out again at Democrat, another little gravel point separated from Remington by a bed-rock spur, where hydraulic work has also been done.

Steep Hollow.

On the point between the forks of Steep Hollow, opposite Democrat, is the small gravel hill called Excelsior, doubtless representing the extension of the Democrat channel. To the north and northwest of Excelsior the bed rock rises rapidly. The channel may have continued a couple of miles farther northeast, but whether it enters under the lava flow or follows the present course of Steep Hollow is uncertain.

Alpha.

On the South Fork of the Yuba several important gravel bodies are found. A few small points covered with quartz gravel occur southeast of Relief, on the south side of the canyon. At Alpha about 75 acres of gravel are preserved, the pebbles consisting chiefly of quartz, quartzite, and a hard conglomerate. Some quartz bowlders on the bed rock reach 5 feet in diameter, but most of the gravel is light and sandy. The banks are 90 feet high, including 20 feet of clay at the top. The amount removed is 5,000,000 cubic yards; only a quarter of that amount remains.

Omega.

At Omega several hundred acres of gravel are exposed and have been extensively worked. The gravel lies on a flat bench and apparently extends southeasterly under the lava. The greatest thickness is 175 feet. The bed consists of 150 feet of gravel covered by 6 feet of clay, above which is again 20 feet of gravel, all showing colors. The lowest stratum contains some large bowlders of granite from the Canyon Creek area, but the main body is composed of smaller cobbles, up to 6 inches in diameter, quartz decidedly predominating. The extent of this channel southward is not definitely known, though a shaft was sunk to bed rock on the Blue Tent ditch, cutting good gravel; its depth is not known. Some distance south of Omega is a small gravel flat called Shellback, at a higher elevation; beyond this the bed rock rises rapidly. Toward the southeast the bed rock also rises, though less rapidly, and gravel is found in places along the rim. At Diamond Creek a small body of quartz gravel is exposed, having a maximum thickness of 12 feet, and covered by a nearly barren Pleistocene morainal bowlder clay.

Extensive hydraulic operations have removed 12,000,000 cubic yards at Omega, the tailings discharging in Scotchman Creek through a 3000-foot bed-rock tunnel. Apparently reliable calculations give $13\frac{1}{2}$ cents as the yield per cubic yard the lowest gravel, of course, being much the richest part of the deposit. About 40,000,000 cubic yards are estimated to be still available for hydraulic mining.

Phelps Hill and Centennial.

It remains to mention the occurrence of many uncertain and puzzling features at Phelps Hill, Centennial, and San Jose shaft. At Phelps Hill, at an elevation of about 4060 feet, 15 to 30 feet of gravel outcrop below the lava for one-half mile. Heavy quartzose bowlders are found on the bed rock. A remarkable disturbance occurs here, the gravel being cut by a fault which throws the west side down about 40 feet. The fault is traceable for at least 400 feet running north-south. The Centennial shaft, $1\frac{1}{2}$ miles south-southeast of Phelps Hill, was sunk in 1887 to a depth of 400 feet, and the bottom of a deep channel was found by drifting from it. Later a tunnel was run 2500 feet south from the place indicated south of Phelps, the elevation being about 4080 feet. The channel was struck at the tunnel level; it is 400 feet in width and carries gravel of quartz and greenstones, the gold being fairly coarse. Work has been suspended, from which it may be inferred that on account of its width the gravel body on the bed rock is not very rich. If, as seems probable, this channel connects with that of Phelps, it can have but little grade.

San Jose shaft.

A mile southwest from the Centennial shaft the San Jose shaft is sunk in the bed of South Fork of Deer Creek to a depth of 340 feet, giving the channel an elevation of between 4000 and 4100 feet, which is stated to be somewhat higher than the Centennial channel. Drifting from the shaft showed the channel to be about 300 feet wide. The gravel is composed of cobbles of quartz and country rock, about 7 to 15 feet thick, covered by 40 feet of clay, above which is lava. There is little doubt that this channel is continuous with the Centennial, and it appears probable that its grade is northward, making it a branch by way of Phelps Hill of the main stream from Relief Hill to Omega. It has been thought by some that this channel might continue to Remington Hill with a southerly grade. This appears unlikely, however, and it is scarcely possible that there should be a continuous channel between Phelps and Remington hills, for the channels at these two places certainly connected with different branches of the old Yuba River. There will probably be found a low divide separating the San Jose channel from Remington Hill and from the Quaker Hill drainage. It is also very unlikely that any of the channels under this lava area had any direct connection with Omega.

On the Iowa Hill and Forest Hill divides a small amount of gravel is exposed on the surface, but the channels preserved below the lava are rich and numerous.

Iowa Hill.

At Iowa Hill a deep channel extends from northwest to southeast across the ridge north of Indian Creek The sharply defined trough is 200 feet deep and is filled with coarse gravel, well cemented in its lower part. The total thickness is over 300 feet. The channel is from 200 to 400 feet wide on the bottom. This gravel has been hydraulicked, except a narrow ridge upon which the town stands. Lighter, quartzose bench gravels extend northeast of Iowa Hill. They have a maximum thickness of 200 feet and are covered by thin rhyolite tuff and andesite. They have been extensively hydraulicked and some ground yet remains.

Morning Star mine.

At Succor Flat a deep and narrow channel belonging to the intervolcanic epoch has been drifted for a distance of 2500 feet; the same channel probably crosses Indian Creek at Monona Flat and finds its outlet at some place on Roachs Hill. South of Indian Creek over 300 feet of gravels crop; southward they thin out with rising bed rock but deepen again near Wisconsin Hill, having at both places the same general character as at Iowa Hill. Between Morning Star and Wisconsin Hill there is doubtless a deep and continuous channel, which is clearly the extension of that underlying Iowa Hill. Extensive hydraulic work has been done both near Morning Star and east of it along Indian Creek, as well as at Wisconsin Hill. A body of higher bench gravels across Refuge Canyon at Elizabeth Hill has also been hydraulicked, but nearly all of this work has ceased during the last decade. Instead extensive drift mining has been carried on. At the Morning Star the deep channel, extending in an easterly direction, has been mined for a distance of nearly 3000 feet; about 7 feet of cemented gravel are extracted, the width of the pay gravel being from 80 to 200 feet. This drift mine has proved among the richest in the Gold Belt. The gravel contained, for a long period, it is stated, $7 per car load, equal to $14 per cubic yard, and the annual production ranged from $25,000 to $150,000.

Waterhouse and Dorn mine.

The Waterhouse and Dorn (or Big Dipper) mine has been working the same channel since 1890 from the Wisconsin Hill side with excellent results. The grade of the main channel is remarkably slight, 2692 feet being the elevation of bed rock at Wisconsin Hill, 2685 feet at the Morning Star, and 2631 at the northwest side of the Iowa Hill channel. In 1899 the workings of this mine were connected with those of the Morning Star, proving conclusively the identity of the channels. A smaller channel pitching into the ridge has been followed some distance in from Grizzly Flat and probably joins the Morning Star channel. A small body of well-worked quartz gravel was found at Kings Hill, chiefly $1\frac{1}{2}$ miles southwest of Wisconsin Hill; it is interesting because of its position between Yankee Jim and Wisconsin Hill and its comparatively low elevation (2550 feet). Four or five acres have been washed here to a depth of 20 feet.

Gravels above Monona Flat.

Above Monona Flat very little gravel is exposed, the andesite tuff resting on bed rock of irregular configuration. At Giant Gap claim, 4 miles west of Damascus, the lava cap is very narrow; below it a gorge-like intervolcanic channel has been exposed. Three miles west of Damascus is McIntyre's claim, where a 1000-foot tunnel has exposed the same or a similar narrow channel. One mile northeast of this is the Colfax claim, showing some quartz gravel probably belonging to a pre-volcanic channel, the continuation of which may be found at Jimtown, three-fourths of a mile north of the reservoir. At Jimtown a shaft 100 feet deep has been sunk, finding quartz gravel and pitching bed rock. No data are available to estimate the yield of Iowa Hill divide since 1849. It probably considerably exceeds $10,000,000.

Peckham Hill and Todd Valley.

To begin now a rapid sketch of the Forest Hill divide it should be stated that comparatively little of the mining work done falls south of the boundary of the Colfax quadrangle. At Peckham Hill a little unsuccessful drifting has been done on the deep and narrow cement channel finding its outlet there. At Todd Valley a body of bench gravel crops, which has been washed at Ponds claim until the overlying lava became too heavy to handle. This gravel is partly cemented, poorly washed, and about 40 feet thick. About 11,000,000 cubic yards have been washed off, the yield of which is given as $5,000,000, but this is probably too high.

Georgia Hill, Yankee Jim, and Smiths Point.

At Georgia Hill, opposite Yankee Jim, a thickness of 100 feet of gravel is exposed below the lava and a few acres have been washed off along the edge. At Yankee Jim a larger area of gravel, from 40 to 100 feet thick, is met with, which toward the east disappears under the lava. The gravel is fairly coarse, being composed of metamorphic rocks with some quartz. The bed rock is at nearly the same elevation as at Georgia Hill and the main channel seems to have had this direction northeasterly and southwesterly, though a somewhat higher channel extended eastward and probably connected with the Smiths Point bench gravel a mile and a half distant and situated on the South Fork of Brushy Creek. The gravel at Smiths Point is 50 feet thick, interstratified with sand. It is estimated that 8,630,000 cubic yards have been removed from Georgia Hill, Yankee Jim, and Smiths Point, and that yield has been about $5,000,000. The amount remaining available for hydraulic work is undoubtedly less than that removed, for the volcanic cap will soon make hydraulic work impossible. One-quarter of a mile east of Georgia Hill the Anthony Clark tunnel has recently been run in a southerly direction for 550 feet and is reported to have shown the existence of a large channel with much granitic detritus. The tunnel was found to be too high, striking the channel above bed rock.

It is believed that the Yankee Jim channel flowed northward toward Wisconsin Hill via Kings Hill. It is also believed that it connects, below the lava, with the Dardanelles channel, though the later intervolcanic channels may have removed much of the earlier accumulations and in some places destroyed the older channel.

Dardanelles, Mayflower, and Bath.

At Dardanelles and Forest Hill the canyon slope has exposed below the lava a long, low trough filled with gravel and rhyolitic tuff. The gravel is moderately coarse, composed of quartz and metamorphic rocks and is well cemented near the bed rock. Above it rests rhyolitic tuff intercalated with some gravel, clay, and sand. The thickness of these two formations varies exceedingly. At the New Jersey claim the gravel is only 8 feet thick and is overlain by rhyolitic tuff. At the Dardanelles it has a maximum thickness of 70 feet. In the region about Mayflower are extensive bodies of rhyolitic tuffs with intercalated gravels, as well as clays and sands, of more doubtful origin. The depth of these accumulations at Mayflower, over the deep channel, is 350 feet. In the intercalated gravels granitic and rhyolitic cobbles are common. At Adams tunnel 178 feet of rhyolitic clays are exposed with two smaller gravel bodies. Again at Black Hawk, Wasson, and Westchester claims similar bodies are exposed. At Bath, again, the same channel is exposed with about 250 feet of overlying gravels and white tuffs. The lower part is a trough 500 feet wide and 100 feet deep, filled in the bottom with washed and rounded bed-rock bowlders composed chiefly of serpentine and greenstone. Above this comes a thick stratum of the usual coarse quartz gravel, and above this a thick series of rhyolitic tuffs with intercalated gravels having a maximum thickness of 30 feet, and containing granite and rhyolite bowlders. The thickness of this series varies from 100 to 250 feet, and it is again covered by 270 to 300 feet of andesitic tuff breccia.

The main pre-volcanic channel enters the ridge at Bath and runs northerly for a mile with very slight grade, then curves west and south, assumes a grade of 60 feet per mile, and passes below Mayflower and Forest Hill to the Dardanelles, where it curves northwest again toward Yankee Jim without leaving the ridge.

The mining operations in this vicinity have been very extensive. The hydraulic operations have mainly ceased, though a considerable amount of ground is still available at the Dardanelles and around the head of Brushy Canyon. At the former place and at Forest Hill 4,850,000 cubic yards have been excavated; at the head of Brushy Canyon probably 7,350,000 cubic yards. Only drift mining is now carried on.

The main old channel has been drifted at Dardanelles for 2500 feet in a northwest direction; the gravel, which is cemented, was here 5 feet deep and 75 feet wide. Mining is still in progress here. The mine is believed to have produced $2,000,000 or more by drifting and hydraulicking.

Jenny Lind and New Jersey tunnels.

Below Forest Hill a number of smaller depressions called "front channels" were worked many years ago from the Jenny Lind and New Jersey tunnels, but no extensive recent work has been done here. The main channel has been reached by the Baltimore tunnel and Excelsior slope, but some drifting ground still remains between these points and the Mayflower. The ground in this vicinity is supposed to have produced $5,000,000, about $1,500,000 being taken from a strip of ground in the New Jersey claim 800 feet long and 300 feet wide.

Mayflower and Paragon.

From the Mayflower tunnel, 4740 feet long, the main channel has been worked, chiefly from 1888 to 1894, for a distance of 3 miles, connecting it with the Paragon workings. A bed of gravel from 2 to 14 feet thick, having an average width of 75 feet, was removed from the bed rock. The yield has been approximately $1,500,000 or $7 per ton of loose gravel delivered. Sixty-six per cent of the bottom gravel was found to pay for extraction. Between the Paragon and the Mayflower, in the bend, is a narrow gorge, 1000 feet long, where the channel is only 25 feet wide and poor in gold. An "upper lead" or streak of gravel inclosed in the rhyolitic tuff, 150 feet above the bed rock, and paying for drifting, is said to exist along the Mayflower channel as well as at the Paragon at Bath, but it has not yet been worked to any extent. Little work is being done at present on the main channel at the Mayflower. The same channel has been worked from the Paragon mine to a distance of 6800 feet north. The width of gravel breasted is 50 feet, depth 2 to 7 feet, yield per ton delivered at surface $10; total yield by hydraulicking $500,000, by drifting $850,000. At the Paragon there exists an upper streak of pay gravel 150 feet above the bed rock; this was followed for 2000 feet until cut off by a channel of intervolcanic erosion filled with andesitic tuff. The width of this upper lead was 225 feet, the depth of noncemented pay gravel 5 feet, and the yield per ton of loose gravel $4.50. The total yield was $900,000. The mine has been operated for 36 years, and the channels are said to be nearly worked out.

Michigan Bluff, Sage Hill, and Byrds Valley.

A portion of what is doubtless the same channel has been preserved at Michigan Bluff. The deposit, which covers about 40 acres, is composed of pure quartz gravel; on the bed rock lie huge rounded quartz bowlders. Some 6,000,000 cubic yards have been removed and a smaller quantity remains. The yield is reported to have been $5,000,000, some of the ground being exceedingly rich. The deposit bears the character of bench gravel. At Sage Hill and Byrds Valley a long, narrow channel, with strong southwest grade, is preserved; the outlet of it at Sage Hill is somewhat lower than Michigan Bluff. It has been worked to some extent but is not so rich as that at Michigan Bluff. Much coarse, rough and crystallized gold was found here as well as in Mad and Lady canyons.

Edwards Hill and Gas Hill.

At Edwards Hill a small patch of partly volcanic gravel has been worked. From here north a number of small gravel points appear, most of which belong to intervolcanic channels. At Gas Hill, however, there is a patch of the same quartz gravel as is exposed at Michigan Bluff. Immediately to the north it is eroded by deeper volcanic channels, but between Hidden Treasure and Damascus a nearly continuous old pre-volcanic channel, having a grade of 70 feet per mile southward, has been found under the lava cap. This is a wide, flat channel filled with about 200 feet of noncemented quartz gravel, sand, and clay. The material is decidedly finer than that of the Bath–Mayflower channel, though some quartz bowlders may be found on the bed rock. It is cut off by two deeper intervolcanic channels, one a mile south of Damascus, another $1\frac{1}{2}$ miles north of Sunny South; between these a fragment of the old "white" channel remains. This channel was first found at Damascus and drifted on until cut off by the intervolcanic channel mentioned. The yield of this part is reported to be $6,000,000. From Sunny South the Hidden Treasure mine has worked the deposit 7700 feet northward; width of gravel breasted 250 feet, depth 4 to 7 feet; yield of loose gravel delivered, $1.75 per ton. The total yield to 1890 was $1,150,000, and up to 1898 probably nearly $2,000,000. Since that time the operations at Sunny South have been discontinued and another tunnel has been started at the Dam claim, one mile farther north, from which the fragment of channel remaining between the volcanic channels is now being mined. The mine has been worked for twenty-three years.

Sunny South mine.

Long Canyon.

The broad ridge between the Middle Fork of the American and Long Canyon, partly falling in Placerville quadrangle, is covered by very heavy accumulations of gravel, rhyolite, and andesite. North and south of this ridge the bed rock rises rapidly, and its configuration shows that below it is a deep trough representing a very important Neocene river course. There is no doubt whatever that this channel forms the eastward continuation of that which enters the ridge at Bath and which once ran a little south of Michigan Bluff. The bed-rock relations alone are sufficient to prove this, but besides there exists the most striking similarity between the deposits at Bath and those on the Long Canyon divide. The outlet of this channel appears without doubt to be located at Ralston's diggings (Pat Goggin's mine). From here the channel makes a curve, entering the Placerville quadrangle for a short distance. Again entering the Colfax quadrangle it must continue below the volcanic masses in a northeasterly direction. Its identity with the channel of French Meadows and Soda Springs (Truckee quadrangle) is indicated beyond all doubt. At no place east of Ralston's, however, is the bottom of the channel exposed until Soda Springs is reached. There appears to be but little pre-volcanic gravel on the Long Canyon divide. Most of the gravel is interstratified with rhyolitic tuffs, forming a series 160 feet thick at Ralston's and at least 250 feet thick at Blacksmith Flat, 4 miles east, on the southern slope of the ridge. Hydraulic operations have been carried on successfully to some extent at Ralston's and at Blacksmith Flat. The gravel everywhere contains granite bowlders, indicating that the stream came from the higher part of the Sierra Nevada. At many places along the south rim in Long Canyon, northeast of Blacksmith Flat, small mining operations have been carried on. At Russian Ravine the surface gravel was hydraulicked with excellent results. In addition to those at Ralston's in Brushy Creek small operations have been carried on at the north side of the ridge and also at a point $1\frac{1}{2}$ miles north of Russian Ravine. At this place it is believed that an inlet exists where the tributary from Duncan Peak entered the Long Canyon ridge. The gravel at this place is 150 feet thick and contains large bowlders of quartz and metamorphic rock. It is covered by heavy masses of rhyolitic tuff. The gold in the gravels embedded in the rhyolitic series is generally fine.

Extensive prospecting operations of recent date show that the main channel on the Long Canyon divide is broad and flat and that the gravels cover large areas but are generally of low grade. Intervolcanic channels do not seem to exist. Hydraulic operations are in progress at Ralston's (Pat Goggin's mine) and at Lynchburg, distant about 3 miles in a southeasterly direction on the southern slope of the ridge.

Connections of the channel systems.—The general Neocene drainage system of this quadrangle has been roughly considered under the heading of "Auriferous gravels," but it remains to indicate in a more detailed way the connection of the channels of the southern part of the area with those of the region between Dutch Flat and North Columbia.

Neocene course of Middle Fork of American.

There is not the slightest doubt that a river corresponding roughly to the present Middle Fork of the American had its source near Castle Peak, thence flowed across to Soda Springs and approximately followed the present Middle Fork, entering this quadrangle under the ridge between Long Canyon and the Middle Fork, and in the southern portion of this ridge curving into the Placerville quadrangle. It entered the Colfax quadrangle again a few miles west of this, and the channel emerged from under the volcanic capping at Ralston's. A tributary from the Duncan Peak region joined it with a general southerly direction. From Ralston's much of it is eroded, but it may be regarded as certain that the main channel continued westward, touching Michigan Bluff and Sage Hill, here receiving an important tributary running nearly due south from Damascus. The deposits of this latter channel are preserved below the lava ridge between Damascus and Gas Hill. Near the latter point it receives a tributary from Last Chance and Deadwood.

Again, east of Michigan Bluff the channel is eroded, but it is certain that its continuation is found at Bath, whence the main channel ran through to Mayflower. Here it made a wide curve and ran southward to Forest Hill and the Dardanelles. Thus far the general course is outlined without uncertainty, but from here on the difficulties begin. This main channel is marked by its heavy deposits of gravel and clay and its broad, well-defined channel. Under the southwestern prolongation of the Forest Hill lava ridge nothing has thus far been found which would indicate that the main old river channel flowed down in this direction. It is true that a narrow channel of the intervolcanic epoch continues down in this direction, but these channels were notably independent of the older and main drainage basins. The intervolcanic channels were excavated after a large part of the old river basins had been filled by accumulations of silt and volcanic mud, and probably also after the tilting of the Sierra Nevada had taken place. Their direction then offers no criterion of the pre-volcanic drainage lines. It would certainly seem as if some fragments of the accumulations of the old channels would have been preserved southwest of the Dardanelles had the channel taken this course. The gravels exposed at Todd Valley offer no solution of the problem, for they are at a higher level and evidently represent a bench filled with gravel after the clogging of the main channel.

There is, however, a solution of this problem which is advanced as having many plausible points, though it can not be said to be free from all objections. This is, that the old channel of the Forest Hill divide emerges at Yankee Jim and Georgia Hill and that its course from there is northward to Wisconsin Hill, thence through the lava ridge and curving eastward to the Morning Star mine, thence to Iowa Hill, crossing the canyon of the present river to Indiana Hill and from there northward to Dutch Flat, whence its course has already been established. This hypothesis in the first place necessitates the existence of a deep and continuous channel between Dutch Flat and Indiana Hill. That such a deep channel exists appears now very probable and may be regarded as certain if the developments south of Dutch Flat in Squires Canyon will show the existence of a deep trough at this place, which it has been asserted was found by the explorations. One of the principal difficulties appears to be the fact that the gravel at Georgia Hill and Yankee Jim differs somewhat in character from that of the Mayflower and Forest Hill. This may be explained by the fact that the river at this point spread over a larger and flatter bottom, which would naturally influence the character of its deposit.

The difficulty which at first glance appears to be an insuperable one, i. e. that of the grades, on closer examination converts itself into an argument in favor of this hypothesis. From the Dardanelles to Yankee Jim is a slight grade which is sufficient for the requirements. From Yankee Jim to Wisconsin Hill the channel would at present have a slight upward grade. From Wisconsin Hill to Iowa Hill it is apparently approximately level. From Iowa Hill to Indiana Hill it has a slight southward grade, and similarly from Dutch Flat to Indiana Hill is a grade which, though slight, is opposite to that which the river according to this hypothesis would have had.

From Yankee Jim to Dutch Flat the Neocene river would have pursued a nearly due northerly course; now it is likely that this river from Yankee Jim to Dutch Flat had originally a very slight grade northward, similar to that of the Neocene river between You Bet and North Columbia. Examinations of channels in various parts of the Sierra Nevada have shown the occurrence of a tilting movement which has affected the grades of the channels according to their direction. Channels running north-northwest to south-southeast would retain their original slight grade. Those running west of this line would have their grades materially increased by the tilting. On the other hand those flowing in a more or less easterly direction from this axis of tilting would have their grade decreased or even reversed. A close examination of the elevations of Indiana Hill, Dutch Flat, Iowa Hill, Wisconsin Hill, and Yankee Jim, will show that in fact the present level character or slight southward grade of these channels is exactly what would follow if the Neocene river, with a northerly course, had participated in a westward tilting of the block of the Sierra Nevada amounting to about 60 or 70 feet per mile.

If this hypothesis be true it solves in an exceedingly satisfactory way a number of the perplexing problems which were presented by the enormous accumulation of gravels in the drainage of the old Yuba River. It increases vastly the watershed of the Neocene stream, which as now outlined extends from the headwaters of the North Fork of the Yuba. The waters of all this territory found an outlet through the narrow channel from North San Juan to Smartsville. In the central part of this drainage area longitudinal depressions existed, bordered on the west by the high diabase ridges of the foothills. All these conditions naturally tended greatly to increase the accumulation of gravels. What has formerly been supposed to be the North Fork of the Neocene American River now becomes the South Fork of the great Neocene Yuba River. The Neocene American River is reduced in size and consists only of the stream coming down from Pyramid Peak by way of Placerville.

Intervolcanic channels on the Forest Hill divide.—During a rather long interval between rhyolitic and andesitic flows new channel courses were established. A disturbance had taken place that increased the slope of the Sierra Nevada, and the streams began active cutting. Thus on the Forest Hill divide there exists a complicated system of narrow, deep channels which in many places have destroyed the old ones. These intervolcanic channels, often called cement channels, belong to at least two systems, the younger being characterized by a large amount of coarse volcanic gravel, rarely containing much gold, and having been formed after the first andesitic flows had already invaded this region. The older system carries thin, mixed metamorphic and volcanic gravel, rarely more than 10 feet thick, there being no gravel at all along certain parts of the streams. This gravel lies on the naked bed rock and is covered by a series of flows of andesitic tuff, the lowest usually fine grained, and referred to as "chocolate" or "cement;" the upper flows consist of the usual tuffaceous breccia. Strata of gravel and sand of mixed character, volcanic and metamorphic, are often found interbedded with the andesitic tuff. Wherever the intervolcanic channels have robbed the old channels they are likely to be rich, though irregular as to their pay. Some of them, however, have been found unexpectedly poor. The gold is usually coarse. The upper gravels in the andesitic tuff sometimes carry gold, though seldom enough to pay for drifting. Some of the volcanic channels have not only cut through the old channels but have eroded small canyons in the bed rock up to a depth of 150 feet. One of the most conspicuous of these crosses Volcano Canyon and is exposed by the Hazard shaft. The grade of these channels is always steep, usually from 70 feet per mile upward.

Channel from Weske tunnel to Peckham Hill.

A whole channel system belonging to this period is buried below the lava of Forest Hill divide. The principal channel can be traced almost continuously from the Weske tunnel, above Michigan Bluff, down to the outlet at Peckham Hill. It cuts the old channels several times and receives numerous tributaries, preserving throughout the same character of deep erosion channel, sometimes barely reaching the bed rock, sometimes cutting deeply into it.

At Peckham Hill and Blue Gravel shaft, in the Placerville quadrangle, it has been opened, but apparently does not pay. For $2\frac{1}{2}$ miles north of Peckham Hill it has not been bottomed, but at Gray Eagle tunnel it has been opened by a tunnel from Owl Creek 2500 feet long and a shaft 360 feet deep. Though somewhat too high the tunnel has followed the channel upstream for several thousand feet. The pay is spotted, the gravel thin, though often rich. In the Mayflower mine the channel is again exposed; it is here called the Orono and has cut down to about the level of the bed rock in the Mayflower channel. From here it has recently been worked for a distance of 2000 feet through the Mayflower tunnel. Again, a little below the mouth of the Mayflower tunnel, in Brushy Canyon, a channel crosses the canyon at a lower elevation than the Mayflower, called the Live Oak. It has been drifted upon northward for 2000 feet; southward it probably joins the Orono channel. Below the volcanic capping between the forks of Brushy Canyon are several intervolcanic channels, such as the Adams, Nil Desperandum, Westchester, Black Hawk, and Wassen, the relations of which are little known.

Farther east, the main channel is again found in the Paragon mine, where it has not quite cut down to the bottom of the old channel. Again it is exposed where it crosses Volcano Canyon, in which the Hazard shaft has been sunk 180 feet; the narrow channel was followed west for 3000 feet and some rich gravel was found. Above there are about 2 miles in which the channel has not been exposed, though a deep tunnel from near Michigan Bluff has been proposed. But above this it has been drifted for over 5000 feet in a westerly direction from the Weske tunnel. In spite of difficult working conditions this enterprise yielded excellent returns, producing approximately $750,000.

A smaller intervolcanic channel, filled with heavy volcanic gravel, crosses the Weske channel near its inlet and thence continues some distance north. It has not been worked to any extent. About a mile north of the Weske channel a small old stream bed has been worked to some extent from the Bowen and Oro tunnels. The latter is about 2500 feet long.

Gravel hills near Weske tunnel.

Above Weske tunnel, confronting Eldorado Canyon, there are a number of smaller gravel hills, most of which have been hydraulicked. Among these are Drummonds Point, Eldorado Hill, and Bachelor Hill. The gravel at all of these places appears to belong to the intervolcanic epoch, and the deposits evidently form part of a somewhat complicated channel system, near the point where the channels from Deadwood join those coming down the main ridge. It is probable that the channel on which the Oro tunnel is driven finds its way down below the level ridge on the western side of the Hidden Treasure tunnel, but it has not been exposed north of the tunnel mentioned.

Sunny South channel.

A narrow intervolcanic channel with heavy volcanic gravel and apparently barren, runs north for some distance from Sunny South, parallel but a little east of the Hidden Treasure channel. At Sunny South it has cut across the latter, obliterating it and eroding some distance into the bed rock below the level of the Hidden Treasure. This is the reason why no quartz gravel can be seen cropping out at Sunny South. About a mile south of Damascus the Mountain Gate channel was cut off by a deeper intervolcanic water course, eroded to a depth of about 150 feet below the older channel. This so-called Blue channel was drifted from the Mountain Gate tunnel, producing $175,000. A little over 2 miles north of Sunny South the same old channel is cut to about the same depth by another intervolcanic channel, finding its way southeasterly to the Dam claim and thence for a mile farther in the same direction to the Mitchell claim. The Dam channel, though narrow and irregular, has been drifted for 2500 feet northwest of the point where it crosses Eldorado Canyon. The Mitchell claim, on the same channel, has also been worked for a distance of 2000 feet. Still another intervolcanic channel, called Bob Lewis channel, has been worked for a thousand feet south of its inlet on the east side of the Mountain Gate channel at Damascus. The principal intervolcanic channel, which probably continues from the Oro to the Blue channel of the Mountain Gate tunnel, has again been exposed at Red Point and worked for a distance of 12,000 feet upstream from the Red Point tunnel, which strikes the channel 2000 feet from its mouth. The Red Point channel is somewhat irregular in width and depth of gravel, and in pay. The average fall of the channel is 75 feet per mile. The width of gravel breasted is 120 feet, the depth from 2 to 12 feet, but generally small. As delivered at the surface the gravel contains $2.50 per ton. Volcanic pebbles are of common occurrence in the washed material. The Red Point mine has been worked for ten years, and during that time been a steady producer. It is immediately capped by the hard andesitic tuff. Large wash bowlders, often 2 or 3 feet in diameter, occur in the gravel. The total production during 5 years from 1888 to 1892 was $308,000, and it is believed that since that time an almost equal quantity has been extracted.

Blue channel.

Red Point channel.

As we approach the higher region of the sierra, where accumulations of pre volcanic gravel were small or did not exist at all, the difficulty of distinguishing between pre-volcanic and intervolcanic channels becomes greater. Strictly speaking, all of the channels must be considered as belonging to the later group, as some erosion necessarily took place in all of them in which bed rock was exposed. Going up toward Duncan Peak we find in general that the grades of the channels increase and that they assume more and more the character of narrow tributaries or gulches.

Hogsback and Black Canyon tunnels.

It is believed that the Red Point channel continues up the ridge. It has indeed been exposed at the Hogsback tunnel $5\frac{1}{2}$ miles northeast from Red Point. The tunnel runs south-southwest 2500 feet, exposing a very deep and narrow gorge with steep westerly grade, and contains very little gravel. Though yielding some gold the channel was not found to pay. About a mile south of the Hogsback channel another deep ravine has been exposed at the Greek mine and the Black Canyon, between which points it is probably continuous. The Black Canyon has been worked for 700 feet eastward. The channel is narrow and very steep, having a grade of 7 feet per 100, with several abrupt falls. On the bed rock rests a few feet of coarse gravel, containing very coarse gold. Above this lies 50 feet of andesitic tuff, gravel, and sand interstratified. No volcanic pebbles were seen in the gravel and the channel probably belongs to the pre-volcanic period. The cost of working this channel is necessarily very high. The inlet of the Hogsback channel is probably found at the low place half a mile north of Secret Canyon House.

Canada Hill.

Near Canada Hill another steep, narrow channel has been exposed which appears to have a very sharp northeasterly grade and the direction indicated on the map. This channel probably crosses Sailor Canyon, entering the Truckee quadrangle, and then joins the main channel, following approximately the Middle Fork of the American somewhere near French Meadows. The western end of the Canada Hill channel is not covered by volcanic rocks but by heavy morainal detritus. A short distance eastward the volcanic rocks begin and cover it to a depth of about 100 feet at the Reed mine, a half mile east of its beginning. A few feet of poorly washed gravel are found in the bottom of the channel, above which are a few feet of clay containing carbonized wood. Above this lies a little massive rhyolite covered by heavy masses of andesitic breccia. This channel has been successfully drifted and in places hydraulicked as far as the place where it enters the high volcanic ridge. It is believed to continue with steep grade underneath this ridge, and its outlet has probably been found at the Sailor Canyon mine 2 miles northeast of Canada Hill. At this place bed-rock tunnels have shown the existence of a narrow channel containing angular, poorly washed gravel covered with a dark clay. The relations at this place are somewhat obscured by considerable masses of morainal material.

Deadwood Ridge.

Deadwood Ridge is crossed by channels belonging to both the earlier and later period which have been extensively worked. The older channel is believed to enter the ridge somewhat south of the Devils Basin, and finds its outlet half a mile north of Deadwood. It is characterized by thicker gravel bodies containing large bowlders of quartz and metamorphic rocks. This channel has been worked from the Rattlesnake mine, on the eastern side of the ridge, and from Reed's and Hornbush's tunnels on the western side. The principal intervolcanic channel has its inlet at the Devils Basin, and has been worked from there for a distance of half a mile, yielding very rich returns. The thickness of the gravel is said to average $2\frac{1}{2}$ feet. The outlet of this channel is probably 3000 feet north of Deadwood and somewhat lower than the adjoining outlet of the older channel. From this side it has been worked 3000 feet eastward without, however, connecting with the Basin tunnel A second intervolcanic channel enters the ridge south of Deadwood and runs in a northerly direction. It has been followed downstream for 3000 feet.

Last Chance.

At Last Chance several channels are known to occur and have been drifted for considerable distance, although leaving some ground as yet unopened. As at Deadwood, there is a pre-volcanic channel and several intervolcanic channels. Both classes follow approximately the same course, though the intervolcanic channels are about 24 feet lower than the others. The gravel and its covering material are similar in character to that of Deadwood. The upper continuation of the Last Chance channels may probably be found at American Hill on the ridge between Lost Canyon and Antone Canyon.

Duncan Peak.

Below the volcanic areas south of Duncan Peak narrow and deep channels have been found, which, however, have not thus far yielded much. One of these extends from Flat Ravine southward for $1\frac{1}{2}$ miles. It has been opened by tunnels at both ends and worked to some extent. Another channel is exposed by Abrams tunnel on the west side of Duncan Canyon. This branch probably joins that from Flat Ravine and, crossing under the lava ridge between Duncan Canyon and the Middle Fork of the American, becomes a tributary of the main Long Canyon channel. Depressions indicating channels also exist below the andesite areas of Big Oak Flat.

Pleistocene gravels.

Pleistocene gravels.—The Neocene gravels derived their rich contents of gold from the disintegration of quartz veins. The Pleistocene gravels, still richer though of less extent, derived their gold not only from the continued disintegration of the quartz veins but also from that stored up in the older Neocene channels as they were gradually destroyed during the process of erosion. As is well known, the Pleistocene gravels were the first to be mined after the discovery of gold in California The miners followed up each stream, and wherever prospects appeared to be good washed the low bars with water easily obtained from the river. A little later the higher benches up to 100 feet above the river were attacked. In the same manner each stream was followed up in case it proved to be valuable and its gravels, wherever occurring, were washed.

All these Pleistocene gravels are now practically exhausted and some have been washed over two or three times. A few Chinese still remain washing the bars of the Middle Fork and South Fork of the Yuba, either in a primitive way by rockers or by wing dams and sluices. Occasionally small patches of gravel not yet mined are found along the river sides.

Practically all the ravines in the western two-thirds of the quadrangle have been mined to greater or less extent. The only barren region is that east of a line drawn from Graniteville to Emigrant Gap, and thence to Monumental Hill and the mouth of Big Valley. Even within this area gold placers have been found on upper Fall Creek about a mile above the crossing of the road from Bowman Lake to Emigrant Gap. A little gold has also been washed near the summit of Grouse Ridge. The Pleistocene gravels of Bear River, Greenhorn River and Steep Hollow have been extensively washed but are now buried below tailings.

Along the North Fork of the American River Pleistocene bars were numerous and rich as far up as Humbug Bar. At Green Valley, south of Towle, and at Hayden Hill, mining operations have been successfully carried on until recently. Above this point the gravels were generally poor, though some have been washed as high up as Sailor Canyon.

The Middle Fork of the American River was noted for its rich gravels, which extended up to a point south of Michigan Bluff. The vicinity of Gray Eagle Bar and American Bar was noted for its important gravel mines during the ten years following the discovery of gold. Some work is even now carried on there. At one point the river makes a wide bend, and a tunnel has recently been run with the expectation of draining this curve and mining the gravels exposed, which are believed not to have been reached by the old miners.

The North Fork of the Middle Fork contained gold up to its head near Canada Hill, while the main Middle Fork is reported to have been relatively poor, though not barren, from a point east of Ralston's mine. Dredging has recently been proposed as a means of working the remaining richer Pleistocene gravels which have been covered by débris from the hydraulic mines, and plants of this kind have been projected for use on the Bear and Greenhorn rivers.

TOTAL YIELD OF GOLD.

It is next to impossible to obtain exact data regarding the total amount of gold produced, as the statistics during the first twenty years after the discovery in 1849 were lamentably deficient. That part of Nevada County situated in this quadrangle has certainly produced $60,000,000. The part of Placer County in the quadrangle has surely produced the same amount, if not much more. To this must be added the large output from Minnesota, Alleghany, and Forest. It is thought that $150,000,000 is not too large an estimate of the total yield, and if the Nevada City and Grass Valley districts, just outside of this quadrangle, be included, the total yield would not be less than $200,000,000. Very few districts in the United States can show such a concentration of wealth in a comparatively small area.

LIMESTONE.

The sedimentary rocks contain, as noted above, a few continuous massive beds or lenses of limestone. Chiefly owing to their situation away from lines of communication they have not thus far been utilized. A small limekiln was once in operation at the small limestone mass along the railroad line $1\frac{1}{2}$ miles north-northeast of Colfax. It has been proposed to quarry for building purposes the gray or black crystalline limestone occurring in the South Fork of Yuba Canyon south of North Bloomfield, as well as that situated along the Bear River 2 miles west of Colfax. Little actual work has, however, been done.

CLAY.

No extensive deposits of clay suitable for pottery are known to occur. Ordinary brick clays are, however, common in the upper part of the Auriferous gravels, as well as in the decomposed clay and residual soil of the andesite and diabase-porphyrite.

BUILDING STONE.

There are no quarries for the purpose of obtaining building stone in the quadrangle. The rocks are in general not well suited for this purpose, being too extensively traversed by seams and joints. The granodiorite affords almost the only available building stone, though its remote situation renders it doubtful whether it will ever be utilized. At the bend of the railroad 3 miles west of Cisco granite has been quarried for railroad building purposes.

SOILS.

Alluvial soils are nearly entirely absent except those covering the few small Pleistocene areas of gravel along the present rivers. The slopes of the canyons are generally rocky and almost denuded of soil. The deep agricultural soils are found along the summits of the ridges and may be characterized as residual soils derived by secular disintegration of the rock in place. Deep red soils are as a rule found on the andesite, gabbro, and diabase-porphyrite areas, while the sedimentary rock of the Bed-rock series is usually shallow, poor, and of a light-gray color.

WATER SUPPLY.

The character and utilization of the streams have already been referred to under the heading "General features." It remains only here to note the existence of numerous springs, generally perennial and very cold. Nearly all of these are located along the contacts of the andesite, rhyolite, or Auriferous gravels with the Bed-rock series. The fragments of old channels covered and preserved by the Neocene accumulations form veritable storage basins for the superficial waters, the importance of which should not be underestimated. The old gravel channels generally contain such a quantity of water that attempts to mine them by shafts are often unsuccessful owing to the expense of pumping. It is often possible to locate the contact in case of doubtful exposures by means of the small springs which are almost sure to be found along it.

No mineral springs are known to exist in the quadrangle.

CHROMITE.

Small irregular masses of chrome iron ore are sometimes found in the peridotite and serpentine. From some of them a small amount of this ore has been shipped. One locality is found near Green Valley in the North Fork of the American River, below Towle. Other small masses of chrome iron have been found in the serpentine of the Forest Hill divide.

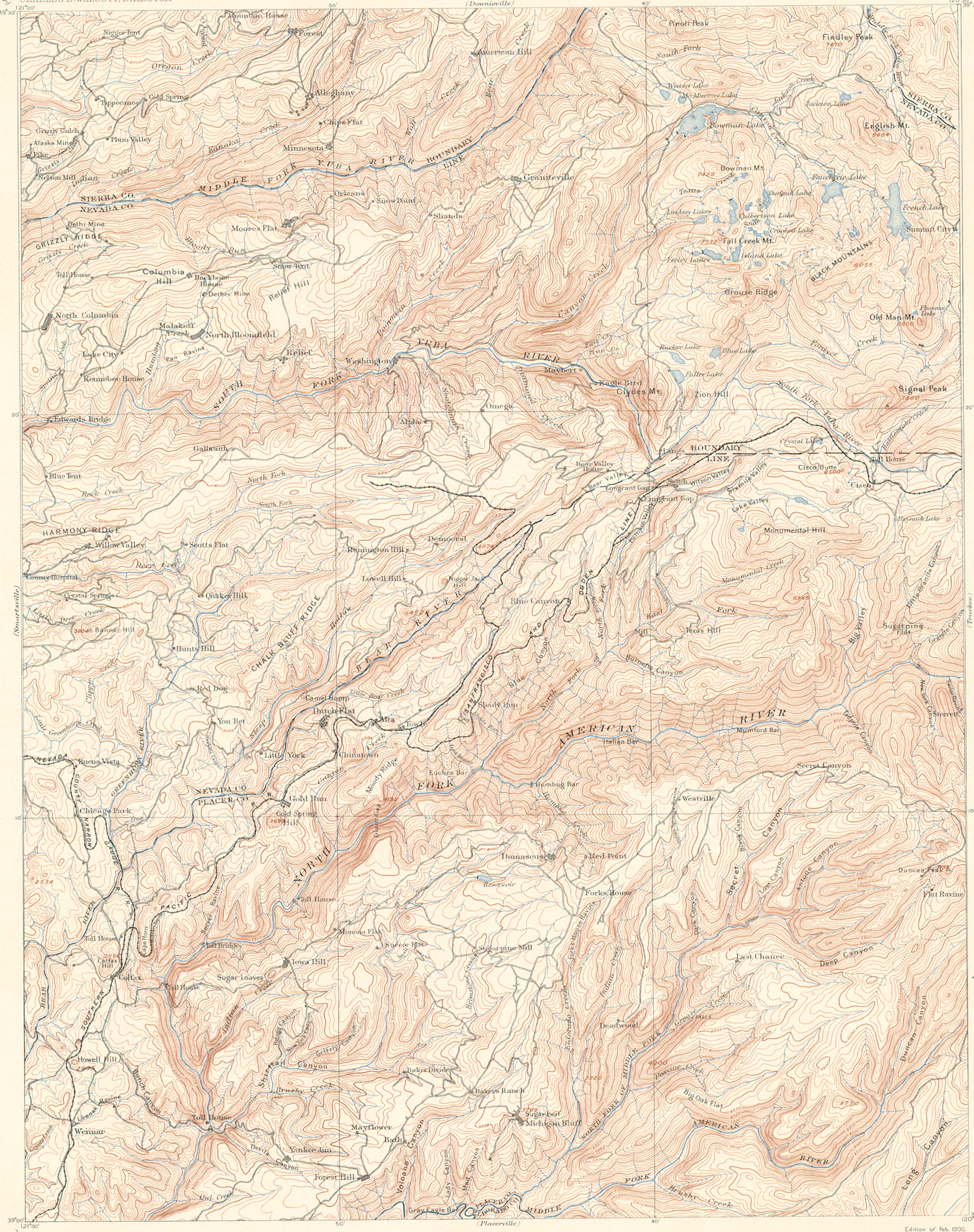
WALDEMAR LINDGREN,
Geologist.

April, 1900.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

TOPOGRAPHIC SHEET

CALIFORNIA
COLFAX QUADRANGLE



LEGEND

RELIEF
(printed in brown)

6945

Figures
(showing heights above mean sea level instrumentally determined)

Contours
(showing height above sea, horizontal form, and steepness of slope of the surface)

DRAINAGE
(printed in blue)

Streams

Lakes, ponds, and reservoirs

Fresh marshes

CULTURE
(printed in black)

Roads and buildings

Trails

Railroads

Bridges

Dams

County boundary lines

Triangulation stations

Henry Gannett, Chief Topographer.
A. H. Thompson, Geographer in charge.
Triangulation by H. M. Wilson.
Topography by H. M. Wilson and A. F. Dunnington.
Surveyed in 1885-87.

Wilson
Dunnington

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.
Datum is mean sea level.

Edition of Feb. 1900.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

HISTORICAL GEOLOGY SHEET

CALIFORNIA
COLFAX QUADRANGLE

LEGEND

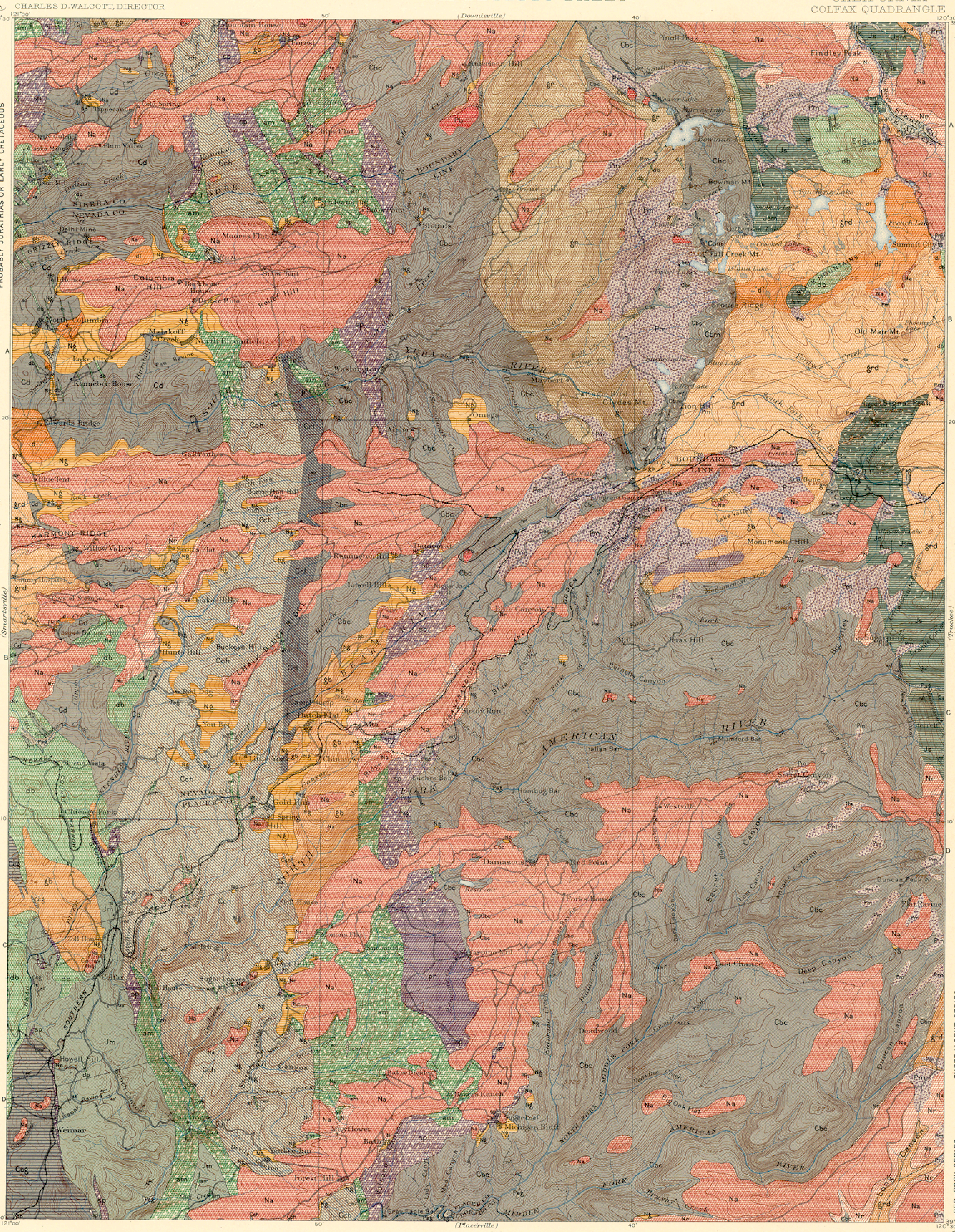
IGNEOUS ROCKS
(continued)

BED-ROCK SERIES — PROBABLY JURATRIAS OR EARLY CRETACEOUS

- **di** Diorite *(including quartz-diorite and augite-diorite)*
- **gb** Gabbro *(including uralite-gabbro)*
- **pd** Peridotite *(with some pyroxenite, partly serpentinized)*
- **sp** Serpentine *(derived in part from peridotite)*
- **db** Diabase, diabase-porphyrite, augite-porphyrite, and hornblende-porphyrite *(massive rocks, tuffs, and breccias)*
- **am** Amphibolite *(mostly schistose, derived from various basic igneous rocks of the bed-rock series)*

Sections

Dip and strike of stratified rocks
Vertical dip and strike of stratified rocks
Dip and strike of schistosity
Vertical dip and strike of schistosity



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A.H. Thompson, Geographer in charge.
Triangulation by H.M. Wilson.
Topography by H.M. Wilson and A.F. Dunnington.
Surveyed in 1885-87.

Scale $\frac{1}{125000}$
Miles
Kilometers
Contour interval 100 feet.
Datum is mean sea level.
Edition of April 1900.

Geology by W. Lindgren
Surveyed in 1887-1895.

LEGEND

SURFICIAL ROCKS
(Areas of Surficial rocks are shown by patterns of dots and circles)

PLEISTOCENE — SUPERJACENT SERIES

- **Pag** Alluvial deposits *(chiefly river gravels, recent and glacial)*
- **Pm** Moraines and glacial drift

SEDIMENTARY ROCKS
(Areas of Sedimentary rocks are shown by patterns of parallel lines. Metamorphism is indicated by short dashes combined with the parallel lines)

NEOCENE

- **Ng** Auriferous gravels *(river gravels, sands, and clays)*

BED-ROCK (AURIFEROUS SLATE) SERIES — JURATRIAS

- **Jm** Mariposa formation *(dark clay slates, sandstone, and conglomerate)*
- **Js** Sailor Canyon formation *(calcareous clay slates with some limestone)*
- **Jsm** Sailor Canyon formation *(contact metamorphic rocks, chiefly mica-schist and hornfels)*

CARBONIFEROUS — (Truckee) Subdivisions of the Calaveras formation

- **Ccg** Clipper Gap formation *(clay slates, chert, and limestone)*
- **Cd** Delhi formation *(black siliceous rocks, rarely schistose)*
- **Cch** Cape Horn formation *(fissile clay slates)*
- **Cr** Relief formation *(chert and quartzite)*
- **Cbc** Blue Canyon formation *(fissile clay slates and quartzitic sandstone, chert and limestone in eastern part)*
- **Cbm** Blue Canyon formation *(contact metamorphic rocks, chiefly mica-schist)*
- **ls** Limestone lenses *(in Carboniferous and Juratrias formations)*

IGNEOUS ROCKS
(Areas of Igneous rocks are shown by patterns of triangles and rhombs. Metamorphism is indicated by short dashes combined with the igneous patterns)

SUPERJACENT SERIES

PLEISTOCENE

- **Pb** Basalt

NEOCENE

- **Na** Andesite *(fragmental, chiefly tuff-breccias)*
- **Nr** Rhyolite *(massive and fragmental)*

BED-ROCK SERIES — PROBABLY JURATRIAS OR EARLY CRETACEOUS

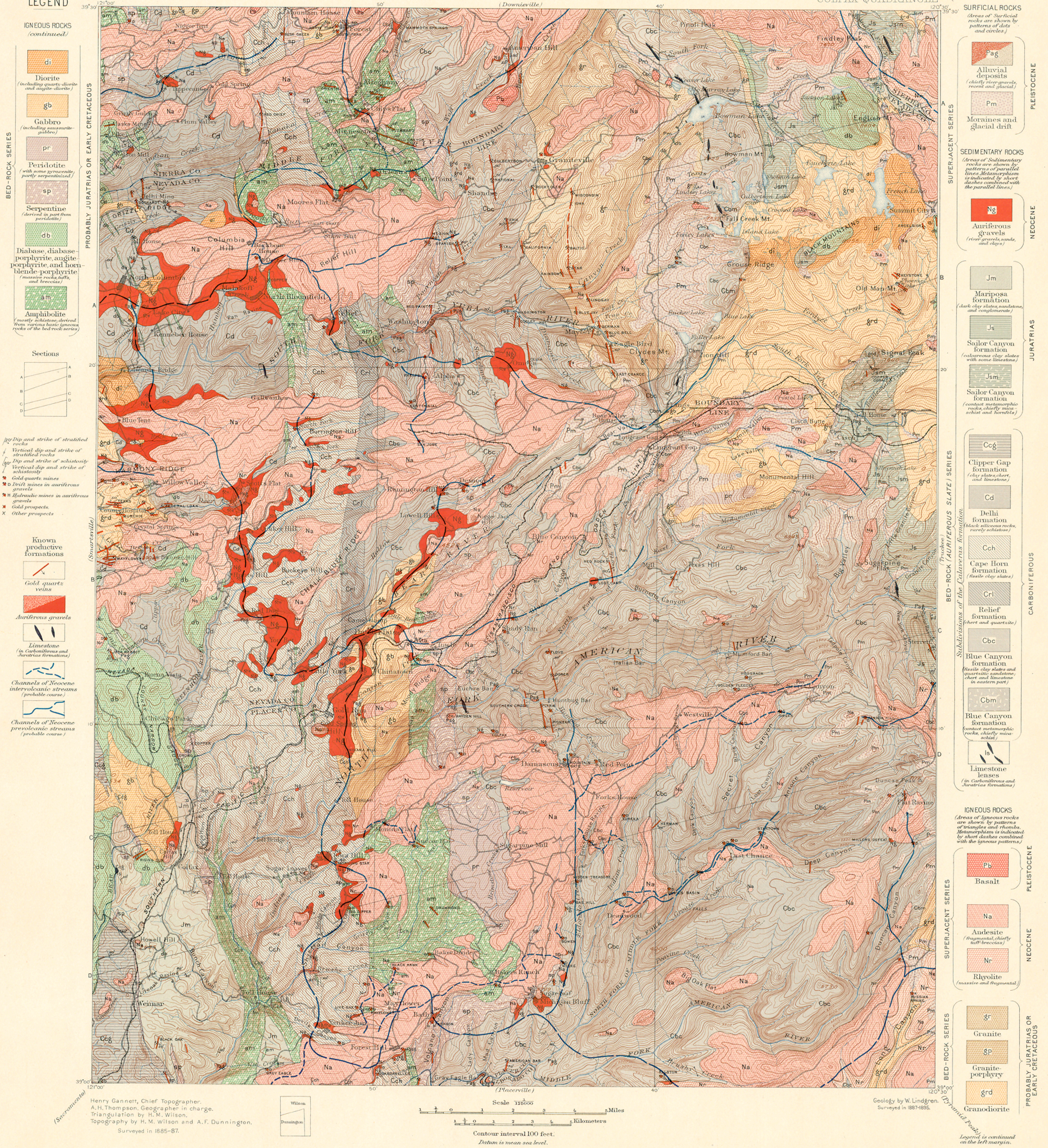
- **gr** Granite
- **gp** Granite-porphyry
- **grd** Granodiorite

Legend is continued on the left margin.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

ECONOMIC GEOLOGY SHEET

CALIFORNIA
COLFAX QUADRANGLE



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Surveyed in 1885-87.

Scale 1/125000

Contour interval 100 feet.
Datum is mean sea level.
Edition of April 1900.

Geology by W. Lindgren.
Surveyed in 1887-1895.

STRUCTURE-SECTION SHEET

LEGEND

IGNEOUS ROCKS
(continued)

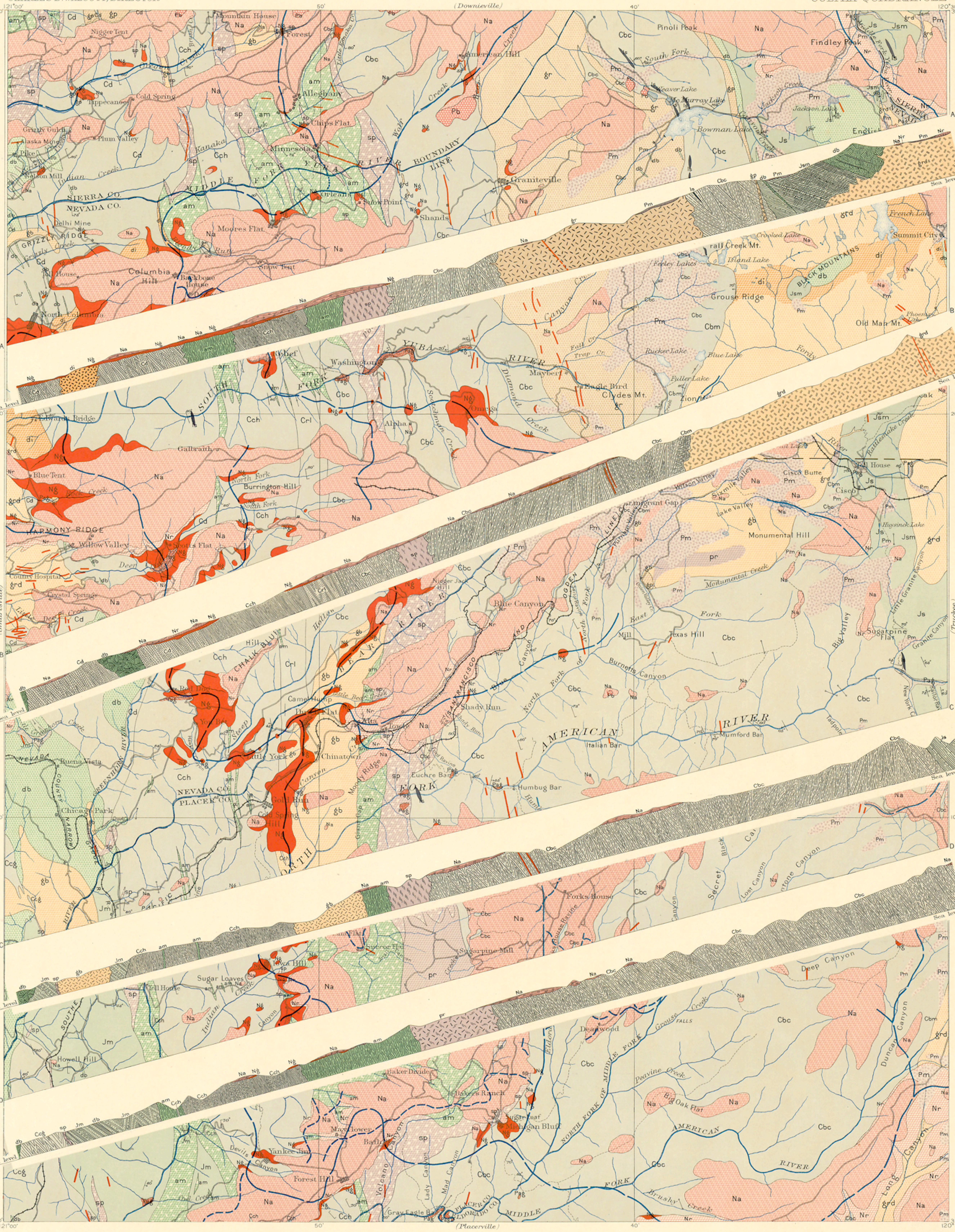
BED-ROCK SERIES — PROBABLY JURATRIAS OR EARLY CRETACEOUS

SHEET SYMBOL	SECTION SYMBOL	
di	di	**Diorite** *(including quartz-diorite and augite-diorite)*
gb	gb	**Gabbro** *(including saussurite-gabbro)*
pr	pr	**Peridotite** *(with some pyroxenite, partly serpentinized)*
sp	sp	**Serpentine** *(derived in part from peridotite)*
db	db	**Diabase, diabase-porphyrite, augite-porphyrite, and hornblende-porphyrite** *(massive rocks, tuffs, and breccias)*
am	am	**Amphibolite** *(mostly schistose, derived from various basic igneous rocks of the bed-rock series)*

Dip and strike of stratified rocks
Vertical dip and strike of stratified rocks
Dip and strike of schistosity
Vertical dip and strike of schistosity

Known productive formations

Gold quartz veins
Auriferous gravels
Limestone (in Carboniferous and Juratrias formations)
Channels of Neocene intervolcanic streams (probable course)
Channels of Neocene prevolcanic streams (probable course)



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Wilson / Dunnington

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Edition of July 1900.

Geology by W. Lindgren.
Surveyed in 1887-1895.

LEGEND

SURFICIAL ROCKS

SUPERJACENT SERIES — PLEISTOCENE

SHEET SYMBOL	SECTION SYMBOL	
Pag		**Alluvial deposits** *(chiefly river-gravels, recent and glacial)*
Pm	Pm	**Moraines and glacial drift**

SEDIMENTARY ROCKS

NEOCENE

SHEET SYMBOL	SECTION SYMBOL	
Ng	Ng	**Auriferous gravels** *(river-gravels, sands, and clays)*

BED-ROCK (AURIFEROUS SLATE) SERIES

JURATRIAS

SHEET SYMBOL	SECTION SYMBOL	
Jm	Jm	**Mariposa formation** *(dark clay slates, sandstone, and conglomerate)*
Js	Js	**Sailor Canyon formation** *(calcareous clay slates with some limestone)*
Jsm	Jsm	**Sailor Canyon formation** *(contact metamorphic rocks, chiefly mica-schist and hornfels)*

CARBONIFEROUS — *Subdivisions of the Calaveras formation*

SHEET SYMBOL	SECTION SYMBOL	
Ccg	Ccg	**Clipper Gap formation** *(clay slates, chert, and limestone)*
Cd	Cd	**Delhi formation** *(black siliceous rocks, rarely schistose)*
Cch	Cch	**Cape Horn formation** *(fissile clay slates)*
Crl	Crl	**Relief formation** *(chert and quartzite)*
Cbc	Cbc	**Blue Canyon formation** *(fissile clay slates and quartzitic sandstone; chert and limestone in eastern part)*
Cbm	Cbm	**Blue Canyon formation** *(contact metamorphic rocks, chiefly mica-schist)*
ls	ls	**Limestone lenses** *(in Carboniferous and Juratrias formations)*

IGNEOUS ROCKS

SUPERJACENT SERIES

SHEET SYMBOL	SECTION SYMBOL		
Pb		**Basalt**	PLEISTOCENE
Na	Na	**Andesite** *(fragmental, chiefly tuff-breccias)*	NEOCENE
Nr	Nr	**Rhyolite** *(massive and fragmental)*	NEOCENE

BED-ROCK SERIES — PROBABLY JURATRIAS OR EARLY CRETACEOUS

SHEET SYMBOL	SECTION SYMBOL	
gr	gr	**Granite**
gp	gp	**Granite-porphyry**
grd	grd	**Granodiorite**

Legend is continued on the left margin.

forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an epoch, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be discovered by observing their relative positions. This relationship holds except in regions of intense disturbance; sometimes in such regions the disturbance of the beds has been so great that their position is reversed, and it is often difficult to determine the relative ages of the beds from their positions; then *fossils*, or the remains of plants and animals, are guides to show which of two or more formations is the oldest.

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are characteristic types, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present.

When two formations are remote one from the other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first.

Fossil remains found in the rocks of different areas, provinces, and continents, afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the color or colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions of the periods, frequently used in geologic writings, are bracketed against the appropriate period name.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the first (Pleistocene) and the last (Archean). The formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations.

Period.	Symbol.	Color.
Pleistocene	P	Any colors.
Neocene { Pliocene / Miocene }	N	Buffs.
Eocene (including Oligocene)	E	Olive-browns.
Cretaceous	K	Olive-greens.
Juratrias { Jurassic / Triassic }	J	Blue-greens.
Carboniferous (including Permian)	C	Blues.
Devonian	D	Blue-purples.
Silurian (including Ordovician)	S	Red-purples.
Cambrian	€	Pinks.
Algonkian	A	Orange-browns.
Archean	Æ	Any colors.

Each formation is furthermore given a letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

The number and extent of surficial formations of the Pleistocene render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined. The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the metamorphic rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Historical geology sheet.—This sheet shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any particular colored pattern and its letter-symbol on the map the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet by fainter color-patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface. In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which exhibits those relations is called a *section*, and the same name is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

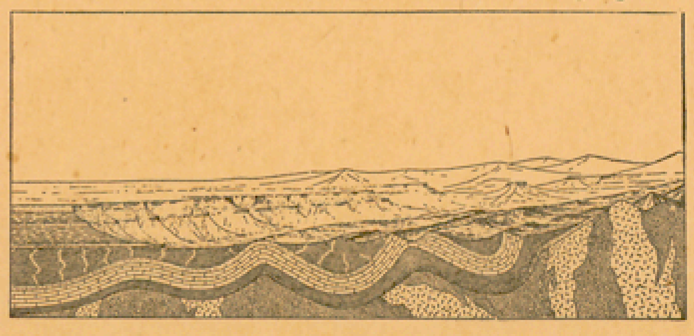

Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane that cuts a section so as to show the underground relations of the rocks.

The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

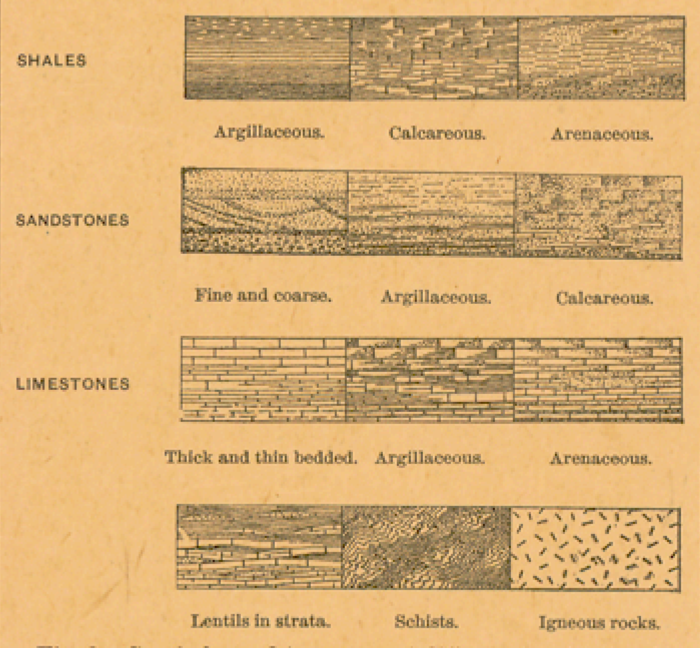

Fig. 3.—Symbols used to represent different kinds of rock.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section.

The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred.

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. But these sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets. That they are now bent and folded is regarded as proof that forces exist which have from time to time caused the earth's surface to wrinkle along certain zones.

On the right of the sketch the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has swelled upward from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata thus rest upon an eroded surface of older strata the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were plicated by pressure and traversed by eruptions of molten rock. But this pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that an interval of considerable duration elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of eruptive activity; and they were deeply eroded. The contact between the second and third sets, marking a time interval between two periods of rock formation, is another unconformity.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections in the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond to the actual slopes of the ground along the section line, and the depth of any mineral-producing or water-bearing stratum which appears in the section may be measured from the surface by using the scale of the map.

Columnar-section sheet.—This sheet contains a concise description of the rock formations which occur in the quadrangle. The diagrams and verbal statements form a summary of the facts relating to the character of the rocks, to the thicknesses of the formations, and to the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest measurements. The average thickness of each formation is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement: the oldest formation is placed at the bottom of the column, the youngest at the top, and igneous rocks or other formations, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied by its name, a description of its character, and its letter-symbol as used in the maps and their legends.

CHARLES D. WALCOTT,
Director.

Revised June, 1897.

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